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GENETIC CHARACTERISTICS OF THE GROUNDWATER REGIME IN THE KHON KAEN DRAINAGE BASIN, NORTHEAST THAILAND

BY

KRIENGSAK SRISUK ©

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND
RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

THE DEPARTMENT OF GEOLOGY

EDMONTON, ALBERTA
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The undersigned certify that they have read and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Genetic Characteristics of the groundwater Regime in the Khon Kaen Drainage Basin, Northeast Thailand submitted by Kriengsak Srisuk in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Geology.

J. Tóth

Dr. J. Tóth, Supervisor

Dr. N.W. Rutter

Dr. S. Pawluk

Dr. K. Muehlenbachs

Carl Mendoza

Dr. C. Mendoza

Dr. R.N. Farvolden, external examiner

Date: 1994 July 20

Dedication

to

my wife, Jang

my sons, Can and Kim

my parents, Fong and Ma

and my mother-in-law, Tanomjit

Abstract

Groundwater is an important water resource for the 20 million people in Northeast Thailand, especially for domestic and agricultural uses during the long dry season. About 17% of the land is affected by soil salinity. Field techniques confirmed by numerical models delineated three hydrogeologic provinces. Huai Yai, Chonnabot and Hin Tank represent type-areas of anticline-syncline, anticline-faulted block, and faulted block provinces respectively. About 67% of the Huai Yai area is occupied by the discharge area. On the contrary, about 68 and 57 % of the Chonnabot and Hin Tank areas are situated in the recharge area.

The Huai Yai province is underlain by three aquifers of clastic rocks of sandstones, siltstones and shales of Phu Phan and Mahasarakham Formations, and sand and gravel units. Three directions of regional groundwater flow recharge into the water divides in the north, west and south, and discharge upward, merging toward each other in the central region. The regional groundwater flow is controlled by topography, anticline, syncline and faults. A Ca-HCO_3 facies is typical recharge groundwater whereas a Na-Cl facies is characteristic of discharge groundwater consisting of average TDS greater than 1000 mg/l.

The Chonnabot Province is underlain by the Khok Kruat and Mahasarakham Formations. The regional groundwater flow travels in the radial direction outwards from the highest elevation and flows along the dip of the bed and plunge of the anticline. Ca-HCO_3 and Ca-HCO_3-Cl with average TDS less than 700 mg/l are major recharge groundwater.

The Hin Tank Province is underlain by the clastic rocks of Phu Tok Formation and areally bounded by four fault lines occupied at surface by creeks and the Chi River. Topography and extensive fractures control regional groundwater flow systems. Ca-HCO_3 and Ca-Na-Cl facies with average TDS less than 500 mg/l are representative of recharge groundwater but Ca-Na-HCO_3-Cl, Na-Cl and Na-SO_4-Cl are typical discharge groundwater.

The patterns of recharge and discharge areas determined by field and model techniques are compatible. The average annual recharge rates in the Huai Yai, Chonnabot and Hin Tank Provinces are approximately 28, 10 and 22 % of precipitation respectively. The priority in groundwater development, on the basis of quantity and quality, are Hin Tank, Huai Yai and Chonnabot Hydrogeologic Provinces.

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List of symbols and abbreviations

API	American Petroleum Institute
ARD	Accelerated Rural Development Office
DLD	Department of Land Development
DMR	Department of Mineral Resources, Ministry of Industry, Thailand
DOH	Department of Health
GREP	Groundwater Resource Evaluation Pilot Project
KKU	Khon Kaen University
NRTC	National Research Council of Thailand
RID	Royal Irrigation Department
RTG	Royal Thai Government
MINTEQA2	Metal Speciation Model
MODFLOW	A Modular Three-dimensional Finite Difference Groundwater Flow Model
PVC	Polyvinyle chloride
TAVWRP	Thai-Australian Village Water Resource Project
SSD	Soil Survey Division
USDA	United States Department of Agriculture
a	annual
amsl	Above mean sea level
cm	centimeter
d	day
epl	Equivalents per liter
epm	Equivalents per million
gpm	Gallon per minute
km	kilometer
l	liter
m	meter
µS	microsiemens
mm	millimeter
s	Second
TDS	Total dissolved solids
Qal	Quaternary alluvium
Qlr	Quaternary laterite
Qsg	Quaternary sand and gravel deposit
Tpt	Tertiary Phu Tok Formation
Kms	Cretaceous Mahasarakham Formation
Kkk	Cretaceous Khok Kruat Formation
Kpp	Cretaceous Phu Phan Formation
Jsk	Jurassic Sao Khua Formation
Jpw	Jurassic Phra Wihan Formation
Jpk	Jurassic Phu Kraduang Formation

Thai terms	**English terms**
Amphoe	District
Ban	Village
Changwat	Province
Daeng	Red
Don	Hill
Hin	Rock
Huai	Creek
Kaeng	Rapid or natural pond
Mae Nam	River
Maha	Large
Nam	Water
Nong	Swamp or depression
Pak	Vegetable
Phu	Ridge or mountain range
Tank	Vertical
Yar	Grass

Chapter 1: Introduction

1.1 Genetic characteristics of the groundwater regime

The cause-and-effect relationship which exists between the hydrogeologic environment (topography, geology and climate) and the groundwater regime is genetic, quantitative and unique, for a given region that is clearly defined by the boundary conditions. This study is an example of the integrated use of hydraulic data, water chemistry and environmental isotopes for tracing groundwater movement. This integrated hydrogeological and hydrochemical study provide a better understanding of the dynamics of the groundwater regime and leads to a realistic estimate of the safe yield of groundwater resources. It also enables the formulation of sound management options.

1.2 Background of the study

Water related problems in Northeast Thailand include: 1) insufficient water supply for domestic and agricultural uses during the long dry season; 2) saline water and soil salinity affecting agricultural lands; 3) water table decline due to industrial exploitation of groundwater in developed areas and 4) groundwater contamination and subsurface environmental impacts.

With the global focus on potable water development during the International Drinking Water Supply and Sanitation Decade (Johnson, 1983) the Royal Thai Government (RTG) launched a National Water Plan. Under this plan numerous research projects were formulated to assess groundwater resources in Thailand, and devise effective water supply development strategies. The Groundwater Resource Evaluation Pilot project (GREP, Wongsawat et al., 1988), a part of the National Water Plan, received technical and financial support from the Thai-Australian Village Water Resource Project (TAVWRP), Department of Mineral Resources (DMR) and Department of Geotechnology, Khon Kaen University (KKU). The present study is a doctoral thesis which constitutes a major part of the research conducted for the GREP project.

Northeast Thailand forms a physiographic province called "the Khorat Plateau". It comprises an area of 170,000 km^2, approximately one-third of Thailand, and lies between latitudes 14° and 19° N, and between longitudes 101° and 106°E. The population in Northeast Thailand reported in 1993 was about 20 million.

The general hydrogeology of Northeast Thailand was studied by Haworth et al., (1966), Piancharoen, (1982) and Johnson (1983). Tuckson, (1983) and Williamson et al., (1989) found that regional groundwater flow patterns in northwest of Kaset Wisai, Northeast Thailand were related to land forms. About 17 % of land in the Northeast Thailand is affected by soil salinity originating from groundwater in the Mesozoic sedimentary rocks and Quaternary sediments (Arunin, 1980). Williamson et al., (1989) applied a two-dimensional groundwater model to determine the flow path for water and the source of salt in the shallow subsurface (20 m depth) in the southwest of Khorat Plateau. General groundwater flow directions and groundwater quality in the town of Khon Kaen were mapped by Srisuk and Lertsirivorakul, (1987) and Yean, (1988). A groundwater availability map for parts of Northeast Thailand at a scale of 1: 100,000 was constructed by Wongsawat et al., (1989). None of these previous studies included the identification of groundwater basins, the quantitative analysis of groundwater flow systems, or the identification of surface manifestations of the groundwater flow regimes in Northeast Thailand.

The Khon Kaen Province, one of the twenty provinces in Northeast Thailand (population 1,463,000, National Statistical Office, 1983), was selected as the site for this study. It is due to the fact that the geologic and hydrogeologic environments in the Khon Kaen Drainage Basin (Figure 1.1) represents most regions in Northeast Thailand. The study area is located near the central part of the Khorat Plateau, between latitudes 16°00' and 16°45' N, and longitudes 102°30' and 103°15' E. It includes parts of the Khon Kaen, Mahasarakham and Kalasin provinces. The present research program covers five study areas of different sizes as shown in Figure 1.1b: (i) the Khon Kaen Drainage Basin (6550 km^2), (ii) Huai Yai (sub-basin A, 830 km^2), (iii) Chonnabot (sub-basin B, 176 km^2), (iv) Hin Tank (sub-basin C, 1110 km^2) and (v) Ban Nong Khai Nun area (9 km^2).

1.3 Purposes and objectives:

The general purposes of the study are to attempt to formulate a physically based conceptual framework and response model to analyze groundwater regimes and numerical models and to develop a standard methodology for exploration of groundwater resources in Northeast Thailand. The specific objectives are to:

1) Define, characterize and delineate hydrogeologic provinces,
2) Characterize the groundwater flow systems that are typical of the various hydrogeologic provinces,
3) Identify the hydrogeologic characteristics and manifestations of typical flow systems,
4) Estimate annual natural water budgets for typical flow systems,
5) Determine the chemical characteristics of typical flow systems, and
6) Construct a sample hydrogeological map and to formulate a standard mapping procedure.
7) Propose possible hydrogeological methods for saline soil amelioration.

1.4 Working hypotheses

Seven working hypotheses have been proposed as follows:

1. It is possible to characterize and distinguish type areas (hydrogeologic provinces) based on physical and chemical parameters of groundwater regimes.
2. Geomorphic features are genetically related to various parameters of the groundwater regimes and, consequently, knowledge of one facilitates parameter estimations for the other.
3. Hydrogeologic province boundaries often coincide with surface water divides and fault lines or fault zones.

4. Geologic structures such as fractures, faults and folds play a significant role in controlling the genetic characteristics of natural groundwater flow systems.
5. Heterogeneous permeability (rock fractures) is a controlling factor in the origin and distribution of surface groundwater manifestations such as soap holes (pimple mounds) in discharge areas.
6. Hydrochemistry of major streams in a drainage basin is affected by regional groundwater discharge.
7. Hydrochemistry in a hydrogeologic province varies naturally in space and time, and is directly linked to the groundwater regime.

1.5 Methodology

1.5.1 Field and laboratory

Pursuit of the study objectives followed four main steps: 1) initial data collection and selection of the study area limits; 2) field and laboratory work (hydrogeologic mapping, well survey, test well drilling, piezometer installation and chemical analysis); 3) additional data collection and flow system analysis and 4) application of hydrogeologic system analysis to groundwater development and management. A flow chart of the hydrogeologic system analysis applied in the present study is illustrated in Figure 1.2.

The present work incorporates studies on both the regional and the local scales. Regional hydrogeological investigations require field reconnaissance, well survey, aerial photo interpretation, geomorphic studies and geologic studies. Hydrogeological maps of sub-basins within the Khon Kaen Drainage Basin (Huai Yai, Chonnabot and Hin Tank Areas) at a scale of 1: 100,000 were made during the field work conducted in 1988-1990. Piezometers and test wells were drilled with a portable top head drive rotary rig supplied by the TAVWRP and a direct rotary machine supplied by the DMR. A total of sixty piezometers were installed with PVC tubing of 63.5 mm (2.5 inches) diameter slotted over the bottom 1 to 2 m. Twenty two test wells were constructed with API casing of 152.4 to

203.2 mm (or 6 to 8 inches) diameter and perforated over the bottom 1 to 2 m. Records of piezometers and wells, and lithologic description of test wells and piezometers are presented in Appendices 1.1 and 1.2. Pumping tests were carried out in these test wells to determine the hydraulic parameters of the aquifers. In addition, eighty six existing water wells were used for monthly monitoring of hydraulic heads. Samples of rain water, surface water and groundwater were collected from 14, 37 and 168 locations respectively in the Khon Kaen Drainage Basin and were chemically analyzed by the GREP project at the Khon Kaen laboratory, DMR regional office. Surface water and groundwater samples were monitored monthly for a period of 14 months (March, 1989 to April, 1990). Ionic concentrations were determined for calcium, sodium, magnesium, potassium, iron, manganese, copper, zinc, silica, bicarbonate, sulfate, nitrate, fluoride as were total dissolved solids. The electrical conductivity and the pH of the water samples were measured both in the field and laboratory. Moreover, some water samples were taken to determine oxygen and hydrogen stable isotopic ratios at the Department of Geology, University of Alberta, Canada. The monthly monitoring for water levels and chemical compositions of waters in the Khon Kaen Drainage Basin are tabulated in Appendix 1.3. My role as a principal researcher in the project included quality control at all stages from data acquisition to final interpretation.

1.5.2 Data base

The major types of basic data used in this study consist of:

1) Topographic maps at a scale of 1 to 50,000.

2) Geologic information (Geologic maps): depth, lithology, age, thickness, and permeability of rock units.

3) Records of four types of wells

Deep wells (Potash exploration wells) drilled by DMR

Existing water wells drilled by DMR

Test wells drilled by GREP

Piezometers drilled by GREP

4) Soil-drainage classes and soil salinity index maps mapped by SSD

5) Land type maps mapped by GREP

6) Regional hydrogeologic data by GREP

7) Hydrogeologic data in the Khon Kaen Drainage Basin collected by GREP, which include:

Topographic elevations of the monitoring wells and piezometers

Monthly measurements of water levels

Chemical compositions of rain water, surface water, dug-well water and groundwater

8) Water level measurements during pumping tests.

Hydraulic measurements were made to the nearest of millimeter. The results of chemical analyses were ascertained by ionic balance calculations. Sufficient care was exercised in culling inferior basic data listed above to ensure an accurate basis for interpretation and synthesis.

1.6 Scope

Chapter 1 introduces the fundamental concept of genetic characteristics of groundwater regime, background of the study, purposes and objectives including working hypotheses, and methodology framework in order to conduct and to achieve this research project. Chapter 2 reviews the fundamental theoretical concepts which are applied within this study, in analyzing regional groundwater flow. It includes some concepts of groundwater regime, hydrogeologic environments, groundwater mapping, hydrochemistry, pumping test analysis, numerical analysis and determination of groundwater balance. Determination and delineation of hydrogeologic provinces in the Khon Kaen Drainage Basin are discussed in Chapter 3 with a local scale case study in Ban Nong Khai Nun Area. Chapter 4, 5 and 6 are the analyses of groundwater flow regime by field (piezometric analysis and geomorphic mapping) and theoretical approaches, including a three-dimensional steady-state finite-difference model for the three type areas: Huai Yai, Chonnabot and Hin Tank Hydrogeologic Provinces. Possible plans for future groundwater resources development in the Khon Kaen Drainage Basin are proposed for the type areas in Chapter 7. Finally, results of the study are summarized and discussed in Chapter 8, and future work and groundwater research in Northeast Thailand, built on the foundation established by the present study are recommended.

Chapter 2: Analysis of groundwater flow

2.1 Groundwater regime and hydrogeologic environment

2.1.1 The groundwater regime

Regional groundwater flow is controlled by the parameters that define the hydrogeologic environment namely: such as, topography, and geology (Tóth, 1970). Distribution of precipitation and surface drainage controls the amount of water available for the subsurface flow systems. Recharge is caused by direct outcrop infiltration and cross-formational leakage. Topographic relief generates gravity-induced potential energy variations on the upper boundary of a flow system (Tóth, 1978). Typically, descending flow occurs under topographic highs, and ascending flow occurs under lows. The effect of topography decreases with aquifer depth and degree of confinement, but increases with increasing relief (Tóth, 1963). Geologic variables such as aquifer , lithology, geometries, internal textures and fabrics, structural configurations that influence groundwater flow do so by controlling hydraulic conductivity and transmissivity. Groundwater flow is directed into and along high permeability zones. Water-bearing and transmission capacities influence flow directions and depend on the stratigraphic and structural framework of a hydrogeologic province. Lithology of the aquifer matrix is an important variable affecting groundwater composition, hydrochemical evolution and transmissivity.

2.1.2 The hydrogeologic environment

A hydrogeologic environment is a combination of topography, geology and climate which are the major controls on the groundwater regime parameters. Each of these components consists of environmental parameters that can be measured, such as actual topographic relief, regional slope, width and depth of the rock framework, rock permeability, precipitation, evaporation, wind speed and solar radiation.

2.1.3 The concept of the Hydrogeologic Province

Tóth (1962 and 1963), using an analytical solution of the Laplace equation, derived an equation for the solution of the distribution of the fluid potential in a mathematical model. The model was set up to simulate a small drainage basin with a water table inclined with a linear slope replicating the topography as a unit basin. He recognized that the flow systems and the unit basin could be determined from the solution to a boundary-value problem. The analytical approach has its limitations, namely; the model is homogenous system and water table configuration can only be represented by simple algebraic functions. These limitations were mitigated by a numerical method by Freeze and Witherspoon (1966 and 1967).

A hydrogeologic province is defined for the present purpose as a geographic region characterized by uniform physiographic, geologic and hydrologic conditions, as described by quantifiable parameters. Groundwater flow in each hydrogeologic province may consist of several flow systems, each of which was defined by Tóth (1963) as *"a set of flow lines in which any two flow lines adjacent at one point of the flow region remain adjacent through the whole region, and that can be intersected anywhere by an uninterrupted surface across which flow takes place in one direction"*.

Groundwater flow systems in each hydrogeologic province which can also be mapped, are characterized by boundary types and patterns, volumes, fluxes and locations as shown in Figure 2.1. The surface of the hydrogeologic province can be divided into recharge areas where the direction of the groundwater flow is away from the water table, and discharge areas, where the direction of groundwater flow is toward the water table (Figure 2.2). The important definitions of natural recharge and discharge used in this study were defined by Freeze (1967) as:

Natural groundwater recharge is that *"water which percolates down through the unsaturated zone to the water table and actually enters the dynamic groundwater flow system. This definition excludes that portion of the moisture surplus that increases the soil moisture content but does not enter the flow pattern itself. The term is not to be confused with the actual areal precipitation which in some cases may lead to groundwater recharge and in other cases may not"*.

Natural groundwater discharge is that *"water which is discharged from the flow system by means of baseflow, artesian feeding of lakes and rivers, springs, seepage and evapotranspiration"*.

Groundwater divide is *"an imaginary impermeable boundary, the symmetry of the flow system creates vertical boundaries beneath the valley and ridges across which there is no flow. In most symmetric systems, groundwater divides of the drainage basin coincide exactly with surface water divides, and their orientation is precisely vertical. In more complex topographic environments, their properties may be lost"* (Freeze and Cherry, 1979).

The delineation of a hydrogeologic province and the determination of the regional groundwater flow pattern within it requires knowledge of boundary conditions, the water table configuration, the hydraulic conductivities of the various formations and the spatial distribution of those formations.

Selection of boundary conditions of the hydrogeologic province and flow systems is a critical step in formulating conceptual models and mapping procedure. In steady-state groundwater flow in the domain, the boundaries largely determine the flow pattern (Tóth, 1962 and 1963, Freeze and Witherspoon, 1966 and 1967). Some typical boundaries for two and three-dimensional problem domains are shown in Figure 2.3.

2.2 Groundwater mapping

Groundwater mapping is the systematic evaluation and cartographical portrayal of hydrogeological conditions of a given area based on subsurface data and observable at the land surface. The method of determining groundwater conditions is judged to be the most valuable in areas where no sources of groundwater information exist, and where surficial phenomena resulting from groundwater can be differentiated from those resulting from surface effects (Tóth, 1966b and Clissold, 1967).

2.2.1 Principles of groundwater mapping

The movement of groundwater is governed by the fluid-potential gradient. The fluid potential, which is the mechanical energy per unit mass of fluid, at a point P of the flow region is given for incompressible fluids by Hubbert's general expression (Hubbert, 1940):

$$\phi = gz + \int_{p_0}^{P} \frac{dp}{\rho} \text{ ....(2.1)}$$

where:

ϕ = fluid potential, g = acceleration due to gravity, z = elevation of the point P above a standard datum, p_0 = atmospheric pressure, p= pressure in the flow region at any point, and ρ = density of fluid. The groundwater potential at a point in the flow region, if the point is open to atmospheric pressure, can be obtained by the expression:

$$\phi = gh \text{ ....(2.2)}$$

where h= elevation to which the water rises above the standard datum (h is often referred to as the hydraulic head). This means that the potential at a point in the groundwater flow region can be calculated by multiplying the elevation of the water level in a well open to the atmosphere, by the acceleration due to gravity.

The gradient of the potential field governing groundwater flow in a rigid, porous unconfined medium under natural conditions is a conservative field force. In the conservative field there are no sources and sinks in the flow domain. The potential field can therefore be described by the Laplace equation,

$$\nabla^2 h = 0 \text{ ....(2.3)}$$

where: ∇^2 is the Laplace operator:

$$\nabla^2 = \frac{\delta^2}{\delta X^2} + \frac{\delta^2}{\delta Y^2} + \frac{\delta^2}{\delta Z^2}$$

The configuration of the potential field determines the direction of groundwater flow. Flow is from higher potentials to lower potentials along the lines of maximum potential gradient, that is, at right angles to lines of equal-potential, provided that the permeability of the porous medium is isotropic. Analytical and numerical models covering a wide spectrum of known field situations were developed by several authors, Tóth (1962 and 1963), Freeze and Witherspoon, (1966, 1967a, and 1967b), Freeze and Cherry (1979) and Anderson and Woessner (1992).

2.2.2 Field techniques in groundwater mapping

Field techniques are basic tools in studying the groundwater of an area. The result of hydrogeological mapping should be a dynamic map which consists of two interconnected parts: surface mapping and subsurface mapping (Erdelyi and Galfi, 1988). The primary objective of the present study is to apply field techniques and theoretical approaches for delineating regional groundwater flow patterns in the Khon Kaen Drainage Basin. There are several types of analyses, discussed by Freeze (1969), that were used to delineate regional groundwater flow patterns within the framework of existing topography and geology. These analyses are: piezometric analyses, surficial evidence, hydrochemistry and low-flow methods.

2.2.2.1 Piezometric analyses

Piezometric analysis involves the use of records of non-pumping water level as measured in wells and piezometers. The water level in a piezometer, which is properly completed and screened interval only at the bottom, is a measure of the hydraulic head at the base of piezometer. Theoretically, direction and magnitude of groundwater flow can be calculated if the spatial variation of the hydraulic head throughout a region is available. The results obtained from measurements of the water levels can be presented in several ways, i.e., as a flow net or hydraulic cross section in a vertical plane or as a piezometric surface. If it were possible to install piezometer nests at every point in question, mapping would be automatic (Freeze and Cherry, 1979). The nests would show an upward-flow component in discharge areas and a downward-flow component in recharge areas. Such a course is clearly uneconomical (Freeze and Cherry, 1979). However, the piezometric analyses described are the only field techniques which define the potential field and the resulting flow system uniquely and accurately. The methods of field evidence, hydrochemistry and base flow analyses are interpretive in nature and must be used in a subordinate or complementary role.

2.2.2.2 Surficial evidence

Surficial evidence such as soil-drainage classes, soil salinity indices, phreatophytic expressions, and quantity and quality of surface waters can be often used as reliable indicator of underlying groundwater conditions. (Tóth, 1966, Meyboom, 1966, Lissey, 1968 and Freeze, 1969). In development of salinity-related problems of both surface and subsurface such as that in the region of Northeast Thailand, the groundwater regime is one of the major factors (Arunin, 1989 and Williamson et al., 1989). The salinity problems in the central part of Northeast Thailand (Tung Kula Ronghai area) were studied using interdisciplinary approaches by the Thai-Australian Tung Kula Ronghai Project (ADAB,1983). The study showed that the salinity problems are related to groundwater flow regimes and several surficial phenomena, such as soil-drainage classes and topographic expressions. Therefore, the hydrogeologic mapping and the method of characterization of surficial evidence which may be related to groundwater regimes must be important.

2.2.2.2.1 Geomorphic mapping

Tóth (1966), Clissold (1967) and Leskiw (1971) mapped surface manifestations related to groundwater flow systems and relationship between soils and groundwater in Alberta. Geomorphic surface manifestations of the flow systems mapped in the study areas include the surficially observed phenomena, such as: soil-drainage classes, soil salinity indices, quality of surface water and springs, and vegetation. The phenomena were observed and mapped in order to provide as a basic tool in making hydrogeologic maps and planning installation of piezometers and test wells.

Topographic elevation

The topographic elevations in the Khon Kaen Drainage Basin are based on topographic maps with a scale of 1:50,000, and a 20 m contour interval covering 9 sheets as follow:

5542 III Ban Khok Sung	5542 II Amphoe Nam Phong	5642 III Amphoe Kranuan
5541 IV Ban Fang	5541 I Changwat Khon Kaen	5641 IV Amphoe Chaing Yun
5541 III Amphoe Chonnabot	5541 II Ban Hin Tank	5641 III Amphoe Borabu

Soil-drainage classes

A detailed reconnaissance soil map of Khon Kaen Province was constructed by Soil Survey Division of the Department of Land Development (1973a). The soil map consists of mapping units with their boundaries. For the purpose of correlation between characteristics of soils and hydrogeologic parameters i.e., recharge and discharge areas, the mapping units in the Khon Kaen Drainage Basin were grouped in terms of soil-drainage classes of the United States Department of Agriculture (USDA, 1951).

The following definitions for soil-drainage classes for use in soil profile description and for this study in terms of soil-drainage class maps in the Khon Kaen Drainage Basin are derived directly from the Soil Survey Manuals (USDA, 1951):

Class 0 Very poorly drained - water is removed from the soil so slowly that the water table remains at or on the surface the greater part of time. Soils of this drainage class usually occupy level or depressed sites and are frequently ponded.

Class 1 Poorly Drained - water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at or near the surface during a considerable part of the year. Poorly drained conditions are due to a high water table, to a slowly permeable layer within the profile, to seepage, or to some combination of these conditions.

Class 2 Imperfectly Drained - water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Imperfectly drained soils commonly have a slowly permeable layer within the profile, a high water table, additions through seepage, or a combination of these conditions.

Class 3 Moderately Well Drained - water is removed from the soil somewhat slowly, so that the profile is wet for a small but significant part of the time. Moderately well drained soils commonly have a slowly permeable layer within or immediately beneath the solum, a relatively high water table.

Class 4 Well Drained - water is removed from the soil readily but not rapidly. Well drained soils commonly retain optimum amounts of moisture for plant growth after rains or additions of irrigation water.

Class 5 Somewhat Excessively Drained - water is removed from the soils rapidly. Many of these soils have little horizontal differentiation and are sandy and very porous.

Class 6 Excessively Drained - water is removed from the soil very rapidly. Excessively drained soils are commonly steep, very porous, or both.

For convenience in mapping of soil-drainage classes in this study, the maps of soil-drainage classes are designed as follow:

Class 0 = VPDS
Class 1 = PDS
Class 2 = IDS
Class 3 = MWDS
Class 4 = WDS
Class 5 = SEDS
Class 6 = EDS

Soil salinity indices

Soil salinity index map was performed by the Soil Survey Division (SSD) of the Department of Land Development (1989) with a scale of 1:250,000. Eight units were defined as following.

1 = Highly salinised soil area
2 = Moderately salinised soil area
3 = Highly salinised soil area
4 = Low topography, moderately salinised soil area
5 = High topography underlain by rock salt
6 = No indication of salinised soil
7 = Mountainous area
8 = Area of numerous salt mounds

Land types

Land types in the Khon Kaen Drainage Basin were mapped based on aerial photos and geomorphic maps of Hokjareon (1986). There are six categories of land types which were classified and mapped as follow:

Rv : Very high and ridge, 20 - 30 m high, 10 - 15 % of moderate slope.
R : High and broad ridge, 10 - 20 m high, 6 - 9 % of gentle slope.
Gu : Gentle undulating to high level plains, 2 - 5 % of gentle to very gentle slope.
Fp : Flood plains with gentle to nearly level slopes (0.5 - 5 %) and locally salt affected.
A : Alluvium plains along major streams with fine sand and lateritic soils, 0 - 0.5 % of nearly level and often salt affected.

Rm : Relic meander belt associated with the Chi and Phong rivers, back swamps, point bars and meanders and depressions, i.e., ponds and low lying paddy field.

Other surface manifestations, flowing wells, natural vegetation, soap holes or pimple mounds and man made objects and local reports which are related to groundwater occurrences, were systematically collected in conjunction with hydrogeologic construction. The results of geomorphic mapping are presented in Chapters 4, 5 and 6.

2.2.2.3 Hydrochemistry

The chemical composition of groundwater can be used as an interpretive tool in hydrogeological studies. A knowledge of the characteristics of typical flow systems, and different sources and ages of the water can be used to make predictions regarding the major chemical processes within a hydrogeologic province. Primary controls on the total dissolved solids (TDS) content of groundwater are: 1) the initial chemical composition of recharge waters; 2) flow path of the water; 3) the distribution, solubility, and adsorption capacity of minerals present; 4) permeability and porosity of the rocks; and 5) anthropogenic influences. All of these processes are inter-related.

2.2.2.3.1 Flow path characteristics

Increasing the length of groundwater flow path results, in principle, in an increase in TDS content. This postulate assumes that chemical equilibrium has not been attained, whereby an excess in soluble mineral is available. The TDS content of water increases and the chemical system tends to move closer to equilibrium, as the flow path lengthens (Chebotarev, 1955 and Back, 1966). Chebotarev (1955) concluded that groundwater tends to evolve toward the composition of sea water. Following is a representation of regional evolution in dominant anion species and flow system, with increasing age and length of flow path (Tóth, 1984):

$HCO_3 \rightarrow HCO_3,SO_4 \rightarrow SO_4 \rightarrow SO_4,Cl \rightarrow Cl,SO_4 \rightarrow Cl$

Local	Intermediate	Regional
Zone of Shallow Flow	Intermediate	Great depth
Active	Sluggish	Quasi-stagnant

Travel along flow path ⟶

Increasing age ⟶

These changes occur as the water moves through active zones of flushing toward zones of old water where flow is sluggish.

Recharge areas are typically low in TDS, higher in dissolved oxygen, low pH, and are often leached of dominant cations (Back, 1961). Bicarbonate content in recharge areas is influenced by availability of CO_2 and soluble carbonate minerals. Recharge areas with developed soil profiles containing large amounts of organic matter contribute significant amounts of CO_2 to percolating recharge waters, due to microbial action. This increased P_{CO_2} in water will facilitate the attack of minerals by producing carbonic acid:

$$CO_2 + H_2O \rightarrow H_2CO_3$$

Further along the flow path, SO_4 becomes the dominant anion because gypsum and anhydrite are considerably more soluble than calcite and dolomite. In cases where sulfate minerals are sparsely available in the flow system, a considerable flow distance is required for SO_4 to become the dominant anion. Deep and very old flow systems evolve toward chloride dominant waters because sulfate and carbonate minerals become lost due to flushing and precipitation, as well as due to the high solubility of chloride minerals. In some groundwater flow systems the water does not evolve past the stage of H_2CO_3 or SO_4 type waters. It is possible for water to undergo a reversal in dominant anions, as in the case of increasing H_2CO_3 and decreasing SO_4, due to biochemical reduction of SO_4 (Freeze and Cherry, 1979).

2.2.2.3.2 Geologic controls

Lithology plays a dominant role in the evolution of chemical composition of groundwater (Back, 1961). Mineral availability, and the solubility of various minerals, govern the resultant water chemistry to a large degree. Often, long flow paths encounter several rock types, and since many chemical reactions in groundwater are dependent on both rock type and water chemistry, ion relationships are governed by the reaction history of the water along the flow path (Tóth, 1984).

Structural features can play a role in controlling the composition of groundwater, principally through alteration of flow paths. Faults not only can provide hydraulic conduits but may also act as hydraulic barriers to flow. Clay deposits associated with fault gouge and disruptions in permeability due to changes in grain orientations and lateral continuity within the aquifer, can in some cases cause groundwater to alter its flow path. This has the effect of increasing residence time and thus greater reaction potential. Depending on the permeabilities and other flow system characteristics, eventually equilibrium will be reached.

2.2.2.3.3 Geochemical controls

Geochemical relationships in many cases provide primary controls on reaction mechanisms. Evaporation from shallow alluvial aquifers can significantly influence the water chemistry. Cl, SO_4, Na, and Ca salts can accumulate in the soil zone from atmospheric precipitation, which is then concentrated by evaporation. Intermittent high intensity storm events may then flush these salts toward the water table. Salt accumulation in arid basin soil zones may also be due to deposition of wind blown salts, transported from discharge areas such as playas.

Dissolution and redistribution of $CO_2(g)$ are important soil zone processed whereas the dissolution of $O_2(g)$ is an important soil-atmospheric process. The resulting levels of dissolved oxygen are sufficiently large at least initially to control the redox chemistry in shallow groundwater (Domenico and Schwartz, 1990). Stability relationships of minerals in solution are affected by many factors including temperature, dissolved oxygen, P_{CO_2}, pH, ionic strength, degree of saturation, and redox potential. Kinetics and reaction rates govern the path by which the system approaches equilibrium.

2.2.2.3.4 Anthropogenic influences

Distributions of major ions in groundwater have been significantly altered in some areas due to human influence. Back (1966) noted that the chloride content within the Atlantic coastal plain had increased dramatically due to contamination from sewage effluent and industrial waste. Jackson and Lloyd (1984) were able to link agriculture practices to increases in NO_3, SO_4, and Cl in the Chalk aquifer in England. These are only selective illustrative examples of changes to facies distributions as a result of contamination.

Pumping may have the effect of inducing leakage from confined aquifers and thus introducing waters having a different character (Jackson and Lloyd, 1984). Large scale pumping may alter regional flow paths, increase the contribution of surface waters to groundwater, and promote salt water intrusion; all of which have the effect of modifying distributions of flow patterns.

Back (1961) developed the concept of hydrochemical facies (water types classified by the dominant major cations and/or anions) by using trilinear plots. The plots indicate which facies are present, while maps and diagrams are used to show their distributions. The hydrochemical facies maps reflect both geochemical processes and groundwater flow patterns. Back's approach allows the geochemical evolution of the groundwater to be described in terms of a progressive sequence of the waters' chemical composition. For groundwater investigations on a regional scale, it is probable that several hydrochemical processes interact. Back's classification is a tool used to study these hydrochemical and hydrogeological processes. Graphical techniques are important in determining which chemical processes are operative, but a detailed understanding of the system is often best obtained using a hydrochemical model to simulate the proposed processes.

2.2.2.4 Low-flow methods

Methods based on low-flow of streams can be applied to the estimation of regional groundwater discharge (Meyboom, 1961). This approach is useful in dealing with permanent streams in humid areas. The separation of stream flow components at any single station in the Khon Kaen Drainage Basin appears to be impossible. This is due to the fact that an area of watershed which is characterized by the Department of Royal Irrigation does not correspond to the selected hydrogeologic provinces of this study. However this method may provide an added tool for the field study of regional groundwater discharge and may be used to estimate an areal basin in water balance. It can also be used to assess the rationality of estimates and measurements of other related components of the hydrologic cycle.

2.2.2.5 Pumping test analysis

Some aquifers are so thick that it is not practical to install a well which fully penetrates the aquifer and thus the aquifer has to be pumped by a partially penetrating well. Because partial penetration induces vertical flow components in the vicinity of the well bore, the simplifying assumption that the well receives waters from horizontal flow is not valid (Kruseman and de Ridder, 1990). Partial penetration causes the flow velocity in the immediate vicinity of the well to be higher than it would be otherwise, leading to an extra loss of head (Boonstra, 1992). If anisotropy is present, with the horizontal hydraulic conductivities (Kr or Kx and Ky) greater than vertical hydraulic conductivity (Kz), this head loss is greater. For long pumping times the effects of partial penetration reach their maximum value for a particular well/piezometer configuration, and remain constant. For these reasons, the pumping test data from the piezometers due to pumping were analyzed on the basis of leaky, nonsteady-state flow with partial penetration and anisotropic aquifer based on the Theis-Hantush method (1964). The governing equation was derived by comparing Darcy's Law for flow in the aquifer and aquitard with the principle of conservation of mass in a radial coordinate system (Hantush, 1969) which is summarized in Dawson and Istok (1991). The following assumptions were made for analytical solution of the test results:

1. The aquifer is bounded above by an aquitard and an overlying unconfined aquifer and bounded below by an aquitard as shown in Figure 2.4.

2. All layers are horizontal and extend infinitely in the radial direction.

3. The initial potentiometric surface in the aquifer (before pumping begins) is horizontal and extends infinitely in the radial direction. The groundwater flow in the aquitard is horizontal, extends infinitely in the radial direction, and remains constant during pumping (zero drawdown). Drawdown of the water table in the aquitard can be neglected when $t \leq S'm'/(10K')$ (the parameters are defined in Figure 2.4, Neuman and Witherspoon, 1969).

4. The aquifer is homogenous and anisotropic. The horizontal and vertical hydraulic conductivities may be different.

5. Groundwater density and viscosity are constant.

6. Groundwater flow can be described by Darcy's law.

7. Groundwater flow in the aquitard is vertical. Groundwater flow in the aquifer is horizontal and directed radially toward the well. This assumption is valid when $K/K' > 100$ (Hantush, 1967).

8. The pumping rate is constant.

9. Head losses through the well screen and pump intake area are negligible.

10. The pumping well has an infinitesimal diameter.

11. The aquifer is compressible and completely elastic. The aquitard is incompressible (i.e., no water is released from aquitard storage during pumping). The assumption is valid when t is greater than 0.036 m'S'/K' (Hantush, 1960).

The drawdown at any point in an observation well is (Hantush, 1964)

$$s = \left(\frac{Q}{4\pi K_r m}\right)[W(u_r, r/B_r) + f(u_r, x, r/B_r, d/m, l/m, z/m)] \text{ ....(2.4)}$$

$$u_r = \frac{r^2 S}{4K_r mt} \quad \text{......} (2.5)$$

where: $$B_r^2 = \frac{K_r mm'}{K'} \quad \text{......} (2.6)$$

$$x = r / m\sqrt{K_z / K_r} \quad \text{......} (2.7)$$

Where $W(u_r, r / B_r)$ is the well function for a leaky aquifer with fully penetrating wells and

$$f = [\frac{2m}{\pi(l-d)}]\sum_{n=1}^{\infty}(\frac{1}{n})[\sin(\frac{n\pi l}{m}) - \sin(\frac{n\pi d}{m})]\cos(\frac{n\pi z}{m})W(u_r, \sqrt{(r/b_r)^2 + (n\pi x)^2}) \text{...} (2.8)$$

where:

$$W(u_r, \sqrt{(r/b_r)^2 + (n\pi x)^2}) = \int_{u_r}^{\infty} \frac{1}{y}\exp[-y - \frac{(r/B)^2 + (n\pi x)^2}{4y}]dy \quad \text{......} (2.9)$$

To compute the average drawdown in an observation well, s_{ave}, equation 2.4 must be integrated between the screened depths $z = d_0$ and $z = l_0$ and divided by the screen length $(l_0 - d_0)$. The result is

$$s_{ave} = (\frac{Q}{4\pi K_r m})[W(u_r, r/B_r) + F(u_r, x, r/B_r, l/m, d/m, l_0/m, d_0/m) \quad \text{......} (2.10)$$

where:

$$F(u_r, x, r/B_r, l/m, d/m, l_0/m, d_0/m) = [\frac{sm^2}{\pi(l-d)(l_0-d_0)}]\sum_{n=1}^{\infty}(\frac{1}{n^2})[\sin(\frac{n\pi l}{m}) - \sin(\frac{n\pi d}{m})]$$

$$[\sin(\frac{n\pi l_0}{m}) - \sin(\frac{n\pi d_0}{m})]W(u_r, \sqrt{(r/B_r)^2 + (n\pi x)^2}) \quad \text{......} (2.11)$$

For convenience, this equation can be written as:

$$s_{ave} = (\frac{Q}{4\pi K_r m})W(\text{partial penetration}) \quad \text{......} (2.12)$$

Values of the function W(partial penetration) can be computed with the computer program TYPE7; average drawdown can also be computed with computer program DRAW7 in Dawson and Istok (1991). The terms in these equations are defined in Figure 2.4.

2.3 Numerical analysis

The field mapping of the groundwater properties and manifestations of regional groundwater flow can be used in the construction of a conceptual groundwater flow model. This method has proven useful in small-scale studies where insufficient well data are available. Freeze (1969) found that in many cases a two dimensional numerical model is sufficient to represent the hydrologic properties of the basin. The numerical model approach using numerical solutions can be used in practice both as reconnaissance tool preceding field investigation and as a predictive tool following the field program.

The Modular Groundwater Flow Model (MODFLOW, McDonald and Harbaugh, 1988) was selected for simulating groundwater flow for Huai Yai and Hin Tank Hydrogeologic Provinces in the Khon Kaen Drainage Basin for the following reasons. First, MODFLOW has produced numerically stable solutions for several researchers (Stoertz and Bradbury, 1989, Brown et al., 1990 and Gilver et al., 1993). It is relatively free of round-off and truncation errors which, if uncontrolled, can lead to an unstable solution. Second, the code is widely used, well documented and available for the personal computer at a minimal cost. Third, the code includes a water balance computation that involves the determinations of flow across boundaries, to and from sources, sinks and storage. The water balance gives information about discharge rates to surface water bodies and of recharge rates across the water table.

Groundwater flow in the Khon Kaen Drainage Basin is complex with strongly three-dimensional flow fields. Thus, a three-dimensional model is necessary to simulate regional flow systems and to calculate basin yield. MODFLOW computes fluxes between specified head-nodes as part of the water balance. When the source code was modified as shown in Table 2.1. MODFLOW still would not calculate the fluxes between adjacent inactive nodes (IBOUND.LE.0). MODFLOW is used to simulate a steady-state flow for only Huai Yai and Hin Tank Hydrogeologic Province. Chonnabot Hydrogeologic Province was not modeled because of inadequate geological control and the limited numbers of piezometers in the province, factors that would make the design of any meaningful model extremely difficult.

The purpose of building a conceptual model is to simplify the physical problem at hand, and organize the associated field data so that the system can be analyzed more readily. Simplification is necessary because a complete representation of the field system is not feasible. Major components of the conceptual model of a groundwater flow system are recharge/discharge fluxes, boundary fluxes and the distribution of hydrologic properties of hydrostratigraphic units within a three-dimensional framework. The hydrogeologic provinces used for the modeling in this study are analyzed and discussed in Chapters 3, 4, 5 and 6. The data utilized to generate groundwater flow models in Ban Nong Khai Nun and Huai Yai and Hin Tank Hydrogeologic Provinces are listed in Table 2.2.

Computer simulation requires representation of the continuous natural system by discretization. The discretized model must correctly represent the geometry of the groundwater domain. This objective is particularly difficult to achieve in regions of heterogeneity and at the irregular shaped boundaries often found in nature. An irregular grid of nodal points is created to which hydrogeologic parameters are assigned, and for which solutions to a set of simultaneous equation are obtained. The equations are solved using the strongly implicit procedure (Anderson and Woessner, 1992). The model uses the horizontal and vertical hydraulic conductivities assigned at each node to calculate a head value, solving the set of simultaneous equations in an iterative scheme. The equation used for the model is the standard groundwater flow equation.

$$\frac{\delta}{\delta X}\left(K_x \frac{\delta h}{\delta X}\right) + \frac{\delta}{\delta Y}\left(K_y \frac{\delta h}{\delta Y}\right) + \frac{\delta}{\delta Y}\left(K_z \frac{\delta h}{\delta Z}\right) = S_y \frac{\delta h}{\delta t} - R \quad \text{..............................} (2.13)$$

with, at steady-state,

$$\frac{\delta h}{\delta t} = 0$$

where K_x, K_y and K_z are the hydraulic conductivities of the medium in the x, y and z directions respectively [L/T]; h is hydraulic head in the medium [L] at (x,y,z); t is time [T]; Sy is the specific yield; x, y and z are space coordinates [L]; and R is a general sink/source term [L/T] that is intrinsically positive and defines the volume of inflow to the system per unit volume of aquifer per unit of time.

For the boundary condition of no-flow, $\frac{\delta h}{\delta x} = \frac{\delta h}{\delta y} = \frac{\delta h}{\delta z} = 0$. For a fixed head condition (i.e., at steady state), h=h(x,y,z) and the shape of the free groundwater surface is h=h(x,y). The computer code, MODFLOW (McDonald and Harbaugh, 1988), was used to solve equation 2.13 for the potential distribution, flow between specified-head cells and the mass budget for individual cells and for the whole basin in three-dimensions. Detailed procedures and various examples of simulations of groundwater flow are discussed in McDonald and Harbaugh (1988), and Anderson and Woessner (1992).

The model assumes steady-state conditions, that is, no significant changes in flow magnitude or distribution occur over time. All groundwater abstraction to date is assumed to have been ineffective in altering the overall flow pattern within the hydrogeologic provinces. The aquifer material is layered, heterogeneous and anisotropic and is considered isothermal and incompressible. The fractured rocks of the Khorat Group are represented as equivalent porous medium. The unsaturated zone is assumed to be in dynamic equilibrium with the water table. The water table boundary was defined at each node by specifying a hydraulic head value equal to 10 and 5 m below the ground surface elevation in recharge areas and discharge areas respectively. The lower impermeable boundary is assumed from geologic influence. Individual hydrogeologic provinces have their own distinct boundary conditions which are discussed in Chapters 4 and 6.

2.4 Determination of groundwater balance

2.4.1 Water balance method

Tóth (1968, 1982) proposed an "approximation method" to estimate some hydrologic and hydraulic parameters in drainage basins. These parameters can be estimated from water-level changes related solely to the transfer of water from recharge areas to discharge areas of gravity-induced groundwater flow systems. The water-level changes can best be observed during times when the exchange of water between the land surface and the saturated zone is at a minimum. His criterion is closely satisfied in the boreal climate of Alberta, Canada during the extended periods of ground frost when the frozen ground acts as an effective hydraulic seal between the land surface and the groundwater. During this period, he assumed that natural supply and use of groundwater such as precipitation and evapotranspiration are minimum or nonexistent. The conceptual framework of the flow system and the parameters are presented in Figure 2.5.

The groundwater coefficient of precipitation (Kp) defined as "*the portion of the annual precipitation added to groundwater in a basin*".

The natural basin yield (Q_B) defined as "*the quantity of flow through an undeveloped basin under natural conditions.*" (Freeze and Witherspoon, 1968 in Tóth, 1968).

Specific basin yield (q_B) defined as "*the volumetric rate of groundwater replenishment per unit surface of the recharge area in unit length of time*".

Safe basin yield (q_{Bsafe}) defined as "*regional safe production rate or amount of groundwater that may be withdrawn on average from a unit area of basin surface per unit length of time without causing adverse hydrologic effects*".

Maximum flux (q_{Bmax}) defined as "*a volumetric flow in a unit length of time through and normal to a unit cross sectional area on the imaginary vertical plane (A_c) beneath the transitional region between the recharge and discharge areas of the basin*".

Maximum basin flow velocity (v_{Bmax}) defined as "*the rate at which macroscopic volume elements of water advance through the rock framework at and normal to the vertical plane* (A_c)".

By applying Tóth's method (1968, 1982) to calculate the hydrologic and hydraulic parameters of the flow systems in the type hydrogeologic provinces several assumptions are made:

1. Any hydrogeologic province may contain one or more flow systems. If there is more than one flow system in the province, the flow systems would be identified and mapped.

2. The water level changes in the piezometers located in the recharge area of these flow systems represent the natural groundwater recharge where water level is least effected by evapotranspiration. The period of selecting water level changes must be, therefore, during the average (arithmetic mean) of the Winter Season (November to February) and Summer Season (March to June). In these periods of the water year, the groundwater system may receive minimum amount of water from precipitation. Otherwise, the calculated natural groundwater recharge through the groundwater flow systems may be overestimated.

3. If the monitoring piezometers are located in discharge areas, the water level must be reduced by about 30% which is estimated from the average percentage of evapotranspiration during this period for this region (Eelaart, 1973). This is due to the additional effect of evapotranspiration.

4. The values of specific yield of saturated porous media at the piezometer site are only estimated from lithology of the aquifers which are tabulated in Table 2.3 (Walton, 1989).

2.4.2 Groundwater coefficient of precipitation

Groundwater conditions in the Khon Kaen Drainage Basin are characterized by certain hydrologic and hydraulic parameters that can be derived from water-level changes related to the transfer of water from recharge areas to discharge areas following the above stated assumptions. The water level changes in piezometers (Δh), should reflect the change in storage of groundwater due to flow from areas of recharge to areas of discharge without effect of evapotranspiration and precipitation. The parameters of interest are approximated as:

$$\overline{S}_{r,t} = |\Delta h|_{r,t} . \overline{S}_y \text{ .... } (2.14a)$$

or

$$\overline{S}_{d,t} = |\Delta h|_{d,t} . \overline{S}_y \text{ .... } (2.14b)$$

or

$$\overline{S}_t = |\Delta h|_t . \overline{S}_y \text{ .... } (2.14c)$$

where: $|\Delta h|_{r,t}$, $|\Delta h|_{d,t}$ are the average of the absolute values of groundwater level changes observed at the recharge and discharge areas of the sub-basin respectively during the time interval t; $|\Delta h|_t$ is the average of the absolute values of water-level changes observed over the entire drainage basin during time t; $\overline{S}_y$ is the average specific yield of the basin's rocks (approximation is based on lithologic materials in Table 2.3); and $\overline{S}_{r,t}$, $\overline{S}_{d,t}$, and $\overline{S}_t$ are the average depths of water removed from the recharge area, added to the discharge area, or transferred across the basin, respectively (Tóth, 1982).

Therefore, the groundwater coefficient of precipitation (Kp) can be calculated as:

$$K_p \cong \frac{\overline{S}_{r,t} * T}{t * p} \text{ .... } (2.15)$$

where T is the total length of time (12 months), t is 4 month period of observation (one season), and p is the depth of precipitation during the time interval T.

2.4.3 Estimation of the specific basin yield, safe basin yield, and maximum basin flow-velocity

The volume of water removed from the recharge area and added to the discharge area during the time interval, t, can be calculated as:

$$V_{bt} \approx \bar{S}_{r,t} * A_r \approx \bar{S}_{r,t} * A_d \text{ ....} (2.16)$$

where V_{bt} is the volume of water transferred in the basin from areas of downward flow to areas of upward flow during time t; and A_r. A_d and A_b areas of the recharge, discharge and total surface areas of the sub-basin, respectively.

The natural basin yield Q_B is

$$Q_B = \frac{V_{Bt}}{t} \text{ ....} (2.17)$$

The specific basin yield, q_B, or volumetric rate of groundwater replenishment per unit surface of the recharge area in unit length of time is:

$$q_B = \frac{Q_B}{A_r} = \frac{V_{Bt}}{A_r \cdot t} = \frac{\bar{S}_{r,t}}{A_r * t} = \frac{\bar{S}_{r,t}}{t} \text{ ....} (2.18)$$

If the seasonal changes of the hydraulic gradients in the flow system are small compared to the average gradient, the total yield of the system (Q_T) during the time of a complete phreatic cycle (T), in a drainage basin containing n flow systems is:

$$Q_T = \sum_{i=1}^{n} Q_{1T} + Q_{2T} + \text{.........} Q_{nT} \text{ ....} (2.19)$$

The safe basin yield, (q_{Bsafe}) or the safe regional production rate, is a useful parameter for determining allowable densities of production wells over a basin surface. The safe basin yield can be estimated as (Tóth, 1968):

$$q_{Bsafe} = \frac{q_B \cdot Ar}{A_b} \text{ ....} (2.20)$$

The maximum flux (q_{Bmax}) and maximum basin velocity (v_{Bmax}) are:

$$q_{Bmax} = \frac{Q_B}{Ac} = \frac{q_B \cdot Ar}{Wc \cdot Dc} \text{ ....} (2.21)$$

$$v_{Bmax} = \frac{q_{Bmax}}{\bar{S}_y} \text{ ....} (2.22)$$

where q_{Bmax} is the maximum basin flux, or the rate of volume discharge per unit area per unit cross-sectional area at the midline (Wc = 1, the width of midline area), Dc is the depth of flow system normal to the unit cross-sectional area (Ac).

The bulk hydraulic conductivity of the province, K_B, is defined from the application of Darcy's Law on a regional scale (Tóth, 1968):

$$K_B = \frac{Q_B}{Ac.\, i_r} = \frac{q_{Bmax}}{i_r} \quad \text{.......................................} (2.23)$$

where i_r is the average regional hydraulic gradient as determined from regional maps of groundwater level.

Chapter 3: Determination of hydrogeologic provinces and aquifer parameters

3.1 Khon Kaen Drainage Basin

3.1.1 Introduction

The Khorat Plateau of Northeast Thailand comprises two basins, namely, the Udon-Sakhon Nakhon Basin and Khorat-Udon Basin, which are separated by the Phu Phan Mountain Range (Figure 1.1a). The Khorat Plateau is a tectonically deformed sedimentary basin with an area of about 170,000 km^2. The Khon Kaen Drainage Basin is located near the central part of the Khorat Plateau, between latitudes 16°00' and 16°45' N, and longitudes 102°30' and 103°15' E. It includes parts of Khon Kaen, Mahasarakham and Kalasin provinces.

The topography of the Khon Kaen Drainage Basin is dominated by the broad alluvial plain of the Phong and Chi rivers. The Chi River flows mainly from west to east. The general physiography of the study area can be divided into three main types of terrain: elongated hills, rolling hills, and lowland alluvial plain. The western and northern regions of the Khon Kaen Drainage Basin are bounded by mountainous and hilly terrain composed of Mesozoic sedimentary rocks whereas the widespread rolling hill terrain in the central region comprises surficial deposits of Tertiary sedimentary rocks, and Quaternary unconsolidated sediments (Hokjareon, 1986).

The Khon Kaen Drainage Basin has a tropical climate, with wet southwest and dry northeast monsoons. Typhoons from the China Sea exert a pronounced effect locally. The wet monsoon begins about the middle of May, increases in intensity from August to September and subsides during October. The northeast dry monsoon begins early in October and ends during the middle of May. The dry wind is associated with low temperatures (15° - 20°C) from November to January and rising temperatures (25° - 33°C) from January to April. Typhoons usually move inland in a northwesterly direction along the Indo-China Coast. Generally, the tails of these typhoons in May and June cause high rainfall in the early part of the Rainy Season. Annual rainfall and pan evaporation vary from about 1100 to 1500 mm and from about 600 to 2000 mm respectively. Average (arithmetic mean) monthly rainfall, pan evaporation and potential evapotranspiration of the Muang Khon Kaen station is presented in Figures 3.1a and 3.1b (Eelaart, 1973 and RID, 1966-1985).

3.1.2 Geology

The sedimentary sequence underlying the Khorat Plateau consists of Mesozoic and Tertiary aged strata belonging to the Khorat Group. The Khorat Group is made up entirely of red beds, originating as shallow water deposits. These beds are generally flat lying to shallow dipping conglomerates, sandstones, siltstones, shales derived from the weathering, erosion and denudation of land uplifted during the late Triassic Indosinian Orogeny (Bunopas and Vella, 1983 and Kozar et al., 1992). The upper part of the sequence contains thick evaporite deposits consisting mainly of rock salt. The minimum thickness of the Khorat Group was estimated to be 2,384 meters (Ward and Bunnag, 1964). Overlying much of the Khorat group are unconsolidated clays, sands and gravels of Quaternary age (Figures 1.1a and 3.2).

The Khorat Group in the Khon Kaen Drainage Basin was deposited unconformably over the unexposed Ratburi Group as shown in Figure 3.2. The Khorat Group consists of the Huai Hin Lat (Thl), Nam Phong (Tnp), Phu Kradung (Jpk), Phra Wihan (Jpw), Sao Khua (Jsk), Phu Phan (Kpp), Khok Kraut (Kkk), Mahasarakham (Kms) and Phu Tok (Tpt) Formations. The hydrogeologic units of the Khorat Group is illustrated in Figure 3.2. The Phu Tok (Tpt) Formation is overlain by unconsolidated clay, sand and gravel of the Quaternary age.

The geologic map of the Khon Kaen Drainage Basin was modified from Chonglakmani and Satayarak (1979) and Hokjareon (1986) as shown in Figures 3.3, 3.4a and 3.4b. The northwest region lowlands and along the back slope of the Phu Meng Ridge comprise the Phu Kradung Formation which is maroon and purple micaceous shales and siltstones. Silicified wood and fossils found in the Phu Kradung Formation indicate an early Jurassic age, and this formation was deposited in a fluvio-lacustrine environment (Piyasin, 1985). The Phu Kradung Formation is conformably overlain by Phra Wihan Formation that is characterized by thick and highly resistant beds which form the Phu Meng Ridge.

Phra Wihan Formation is composed of quartzitic sandstones interbedded with thin laminated siltstones. This formation was deposited in a fluvio-lacustrine environment. It is overlain by the Sao Kua Formation which consists of fine grained sandstones and micaceous sandstones and siltstones.

An exposure of the Sao Kua Formation occurs in the relatively flat land in the western region. It is comformably overlain by the thick, resistant and light-colored pebbly sandstones, coarse-grained sandstones and conglomerates of the Phu Phan Formation.

The Phu Phan Formation is characterized by medium to large scale cross bedding. It was deposited in a deltaic environment during lower Cretaceous times (Piyasin, 1985) and formed nearly flat-topped hills within the rolling terrain in the west. In the eastern region of the Phu Meng Ridge, the ground is supported by the Khok Kruat Formation which is composed of medium to fine grained sandstones and siltstones. The Khok Kruat Formation was deposited in a lagoonal environment.

During the upper Cretaceous times, shales, sandstones and siltstones of the Mahasarakham Formation were deposited in a salt marsh to tidal flat environment (Piyasin, 1985). Consequently, claystones and shales interbedded with two to three layers of evaporites (halite, gypsum, anhydrite, carnallite and sylvite) varying in thickness from 10 to 170 m (Japakasetr and Suwanich, 1984) were deposited in the upper part of the Mahasarakham Formation. These evaporite beds pinch out at the flanks of synclinal and anticlinal structures (Figures 3.4a and 3.4b).

The Quaternary deposits can be divided into four lithostratigraphic units comprising sand and gravel deposits (Qsg), laterite deposits (Qlr), loess deposits (Qls) and alluvium (Qal).

The Khorat Plateau evolved through six tectonic phases, four of which were orogenic events. The sequence of orogenic events produced a structural style characterized by multidirectional fault and fold patterns. The tectonic events recognized from seismic sections by Kozar et al. (1992) are: (1) Early Carboniferous Variscan orogeny, probably a compressional event; (2) Late Carboniferous rifting; (3) Mid Triassic Indosinian to Early Tertiary orogeny, a compressional event; (4) Late Triassic to Early Tertiary interior basin sag, which was uniform subsidence; (5) Early Tertiary compressional orogeny; and (6) Early Tertiary to present uplift and erosion. The tectonic events most relevant to this study are the Early Tertiary compressional orogeny and Early Tertiary to present uplift and erosion.

Interior sag and associated deposition culminated during the Early Tertiary most likely during the Paleocene or Eocene; the Khorat Plateau was subjected to contraction from both the northeast and west. These events resulted from backarc compression of the Shan microcontinent to the west and continental collision with the South China plate to the northeast (Kozar et al., 1992). Compression and collision have produced spectacular examples of inversion caused by reverse slip along bounding faults of grabens and half grabens. Reactivation has caused displacements of basement from 30 to 300 m as observed by Kozar, et al. (1992). Thrust faults are common such as those observed at Nam Phong area in the northern region of the Khon Kaen Drainage Basin. During the Early Tertiary a compressive stress field developed and the entire Khorat region was subject to uplift and erosion.

In the Khon Kaen Drainage Basin, fault zones are oriented northeast and north to northwest. The Chi and Phong rivers developed along the fault plane traces at the ground surface. There is some evidence of strike slip faulting i.e., offsets of stream courses (approximately 1070 m, Figure 3.12) and brecciated sandstones and siltstones of the Phu Tok Formation found in the stream bed of the Chi River at Ban Nong Bua De Me located about 12 km south of the town of Khon Kaen (Plates 3.1 and 3.2). The magnitude of vertical displacement is unknown. The Tertiary-Mesozoic basin forms a broad syncline-anticline with fold axes trending north-northwest to south-southeast and plunging to the south and southeast (Chonglakmani and Satayarak, 1979). The extensive Khorat Group exhibits sub horizontal to low angle bedding dips varying from 5° to 20°.

The stratigraphy of the Khon Kaen Drainage Basin was determined from existing water well logs and from data recorded in potash exploration holes. Eleven potash exploration logs for wells K54, K53, K110, K116, K96, K114, K117, K59, K36, K57 and K89 (Japakasert and Suwanich, 1981, 1982, 1983 and 1984) were compiled to evaluate the subsurface geology. The deepest well, K89, was drilled to a depth of 1000 m. Most wells penetrated the rock salt beds of the Mahasarakham Formation. Three-dimensional fence diagrams of the area were constructed as depicted in Figures 3.4a and 3.4b.

3.1.3 Hydrogeology

3.1.3.1 Hydrostratigraphy

Groundwater in the Khon Kaen Drainage Basin occurs in both original and secondary rock voids. The primary porosity in clastic sediments such as sands and gravels, sandstones and conglomerates are the original intergranular voids sometimes modified by cementation. Secondary porosity (fracture and joint) found in the Khon Kaen Drainage Basin is probably related to faulting and associated tectonic deformation which affected Mesozoic sandstones siltstones and shales during the early Tertiary.

Water table records that were obtained from 168 water wells and piezometers represent well depths ranging from 15 to 110 m from ground surface and drilled into several geologic formations as shown in Figures 3.4a and 3.4b. The average annual non-pumping water level (average of 12 monthly measurements) of each location is presented as a contour map of equipotentials (Figure 3.5).

The hydrostratigraphy of the Khon Kaen Drainage Basin is presented in terms of the geologic successions, with lithostratigraphic divisions and integration of the bulk permeability and regional hydraulic continuity, reorganized as hydrogeologic units. Each hydrogeologic unit, as defined by Tóth (1978), *"is a single stratum or combination of strata that function in bulk as either a water-bearing or a water-retarding rock complex relative to adjacent strata"*.

The hydrogeologic units in the Khon Kaen Drainage Basin are designated as aquifer, aquitard and aquiclude.

A representative hydrostratigraphy in the Khon Kaen Drainage Basin consists of the following hydrogeologic units (Figure 3.2).

Major aquifers are: Kpp, Kms, Tpt and Qsg.

Aquitards are: Kkk and Qal

Aqicludes are: rs and Jpk

The lower Khorat Group comprises Huai Hin Lat, Phu Kraduang, Phra Wihan and Sao Khua Formations within the Khon Kaen Drainage Basin which show predominantly low hydraulic conductivities (< 1.27E-07 m/s, as shown in Table 3.1), and well yields in these Formations are relatively low (<0.5 l/s, Ramanarong, 1985). Therefore, it is treated as an aquitard. For this regional groundwater study those formations which are composed of lime conglomerates, sandstones, siltstones and shales, are designated as the Jpk hydrogeologic unit (Phu Kraduang hydrogeologic unit, Figure 3.2 and Table 3.1). Four main lithostratigraphic divisions are considered to be potential aquifers, namely: the Quaternary sand and gravel unit (Qsg), shales, siltstones and sandstones of the Phu Tok unit (Tpt), shales, siltstones and sandstones of the Mahasarakham unit (Kms), and conglomeratic sandstones and siltstones of the Phu Phan unit (Kpp). Pumping test results indicate that hydraulic conductivities of aquifers in the Khon Kaen Drainage Basin are variable from place to place and from formation to formation as shown in Table 3.1. The hydraulic conductivities range from 2.47E-05 to 6.48E-05, 4.28E-06 to 8.98E-05, 1.16E-07 to 8.57E-06 and 1.16E-07 to 3.7E-07 m/s for the Quaternary sand and gravel unit (Qsg), Phu Tok (Tpt), Mahasarakham (Kms) and Phu Phan units (Kpp) respectively. These aquifers yield variable amounts of water ranging from 1.11 to 46.30 l/s.

3.1.3.2 Hydrochemistry

3.1.3.2.1 Rain water and surface water

The chemical composition of precipitation over the Khon Kaen Drainage Basin varies in both time and space. Rain water compositions for samples collected during 1988 to 1990 are shown in Table 3.2a. The rain water samples, plotted on the Piper trilinear diagram modified by Galloway and Kaiser (1980) all lie within the Ca-HCO_3 water with TDS contents ranging from 15 to 140 mg/l (Figure 3.10). Table 3.2b shows averaged ratios of Na, K, Ca and Mg cations to chloride ion for rain waters and groundwaters in recharge areas of Huai Yai, Chonnabot and Hin Tank areas. By and large, the groundwaters exhibit higher ratios of cations to chloride in the rain waters.

Surface water samples collected from the Khon Kaen Drainage Basin can be classified into three groups: 1) perennial streams of Phong and Chi rivers, 2) artificial reservoirs, e.g., Ubolrat Dam, 3) topographic depressions and natural swamps. The surface waters show a wide variety of chemical constituents (Table 3.3). Surface water samples of perennial streams were collected from 15 locations along the Phong and Chi rivers (Figure 3.6). Average total dissolved solids contents (TDS) for these samples range from 100 to 800 mg/l. The chemical compositions of the Phong River vary from Ca-HCO_3 upstream to Ca-Na-HCO_3-Cl downstream (Figure 3.6). The Chi River however exhibits Na-Cl and Ca-Na-HCO_3-Cl facies, with all samples exhibiting relatively high TDS contents. Chemical compositions of artificial reservoirs show low TDS contents and a Ca-HCO_3 type. However, water samples collected from selected topographic depressions and swamps are mainly Na-Cl and Ca-Na-HCO_3-Cl water.

The average TDS contents of surface water along the Phong River is much lower than the Chi River as shown in Figure 3.7a and 3.7b. The TDS contents in the Phong-Chi River in the southeast becomes less concentrated in the Ca-Na-HCO_3-Cl facies (Figure 3.7). The TDS content variations at the upstream end of the Phong River are less than 40 mg/l, the maximum salinity barely exceeding 150 mg/l (Figure 3.7a). Seasonal variations in

TDS contents of the surface water can be observed at the upstream end of the Chi River at SW15 in the southwest part of the Khon Kaen Drainage Basin. The TDS contents vary from 132 mg/l in the Rainy Season (July to November) to 714 mg/l in the Summer (March to June). It is postulated that the variability in TDS contents of surface along the courses of the rivers may be effected by groundwater discharging from different recharge regions.

During the dry period groundwater discharging into the river increases TDS contents of the river water. Subsequently the river water is diluted by precipitation in the Rainy Season. The high mineralization of surface water in the Summer (March to June) and Winter (December to February) Seasons is due to the stream being fed by groundwater discharge rather than simple evaporative concentration. It is supported by the contrasting chemical compositions of surface water samples collected from the western (SW15) and eastern (SW16) sides of the Chi River (southwest of the Khon Kaen Drainage Basin). The TDS contents of surface water samples from SW15 and SW16 show significantly different chemical characteristics (Figure 3.8).

Piezometers P50 and P78 were drilled on the western and eastern banks of the Chi River respectively (Figure 3.6). Figure 3.8 shows that TDS in well P78 (annual average of 13155 mg/l) is much higher than P50 (annual average of 2156 mg/l) throughout year. The TDS contents of the groundwater in wells located on both sides of the river banks exceed those of the river waters. The differences in mineralizations of surface water and groundwater may be caused by groundwater discharging from different flow paths. The surface water and groundwater on the eastern side (SW16 and P78) of the Chi River may be fed by groundwater discharging from the Hin Tank area in the eastern region, whereas the surface water SW15 and groundwater in well P50 is fed by groundwater that has evolved from the Chonnabot area.

3.1.3.2.2 Groundwater

Groundwater in the Khon Kaen Drainage Basin exhibits TDS contents ranging from 100 to 44000 mg/l. The TDS contents vary spatially. Figure 3.9 shows the distribution of average TDS contents collected from existing water wells in the Khon Kaen Drainage Basin. The lowest TDS contents of groundwater are found in Quaternary sand and gravel deposits (Qsg) ranging from 100 to 500 mg/l. TDS contents in the shales and sandstones of the Mahasarakham Formation (Kms) are diverse and not directly correlated with its lithology. Nevertheless, hydrochemical facies in Figure 3.10, were plotted in plan view as shown in Figures 3.11. Nine major hydrochemical facies of groundwater that can be identified in the Khon Kaen Drainage Basin are as follows (the facies are indicated in the Piper diagram in Figure 3.11):

Facies 1 Calcium-bicarbonate (Ca-HCO_3)

Facies 2 Calcium-sodium-bicarbonate (Ca-Na-HCO_3)

Facies 3 Calcium-bicarbonate-chloride (Ca-HCO_3-Cl)

Facies 4 Calcium-chloride (Ca-Cl)

Facies 5 Calcium-sodium-chloride (Ca-Na-Cl)

Facies 7 Sodium-bicarbonate-chloride (Na-HCO_3-Cl)

Facies 8 Calcium-sodium-bicarbonate-chloride (Ca-Na-HCO_3-Cl)

Facies 9 Sodium-sulfate-chloride (Na-SO_4-Cl) and

Facies 10 Sodium-chloride (Na-Cl).

Calcium-sodium-bicarbonate (Ca-HCO_3) groundwater predominates in recharge areas in northwestern and northeastern regions. Groundwater in these areas exhibits TDS contents from 200 to 1000 mg/l. Calcium-sodium-bicarbonate (Ca-Na-HCO_3) facies occurs in the southwestern region. Sodium-bicarbonate-chloride (Na-HCO_3-Cl) water is common in the southeastern region comprising groundwater contained in fractured shales and sandstones of the Phu Tok unit (Tpt). Calcium-chloride (Ca-Cl) water is locally found in the central region of the Khon Kaen Drainage Basin and in the area adjacent to Ca-Na-HCO_3 water. Calcium-sodium-bicarbonate-chloride (Ca-Na-HCO_3-Cl) water occupies discharge areas in the western, southwest and central regions near the Chi River. Calcium-sodium-chloride (Ca-Na-Cl) facies water exists only in the northwest region. Sodium-chloride and sulfate water is found locally in topographic lowlands at the central and southwestern regions. Sodium-chloride (Na-Cl) facies water, is the predominant water type in the topographic lowlands that are the flood plains of the Chi and Huai Yai Creek in the central and eastern regions. The relationship between regional groundwater flow and hydrochemistry is analyzed for individual hydrogeologic provinces in Chapters 4, 5 and 6.

In examining regional distributions of water table configurations (Figure 3.5), the distribution of TDS contents in various aquifers (Figure 3.9), hydrochemical facies of surface water and groundwater (Figures 3.6 and 3.11), four main regions of groundwater flow regimes can be differentiated as follows:

1) Northeast region (southeast of Amphoe Nam Phong): the region is underlain by shales and siltstones of the Mahasarakham unit (Kms) and unconformably overlain by the Qsg unit. Together these units form the elongated and undulating terrain. TDS contents in the sand and gravel unit is less than 500 mg/l in the recharge area and increases along the flow path (1000 to 2000 mg/l) in the shales and sandstones of the Kms unit in the south and west of the region.

2) Southwest region (Huai Yai area): the region is underlain by a series of Mesozoic sedimentary rocks of the Khorat Group and Quaternary deposits. The distribution of TDS contents of groundwater in the aquifers vary from place to place and formation to formation. The general trends of TDS contents are increasing from less than 500 mg/l in the west and north, to greater than 3000 mg/l in the lowland along the west of the Phong and Chi rivers. There are several spots of high TDS contents (>10000 mg/l) in the Kms located in the center of the region.

3) Southwest region (north of Amphoe Chonnabot): Suan Pa Muncha ridge, is underlain by shales, siltstones and sandstones of Khok Kruat (Kkk) and Mahasarakham (Kms) units, and unconformably overlain by a thin veneer of sand and gravel unit (Qsg). The hydrostratigraphy of this region is similar to the Huai Yai region, but the topographic relief is relatively high and predominantly rolling terrain. The TDS distribution of

groundwater is relatively low in the central region and increases near the lowlands of the Chi River and other creeks.

4) Southeast region (Hin Tank area) is occupied by shales, siltstones and sandstones of the Phu Tok unit (Tpt). The regional groundwater flow pattern radiated in various directions from the central region to the periphery. The region formed by a broad syncline with its axis northwest to south east and plunge to the southeast. The distribution of TDS contents of groundwater is relatively low (< 500 mg/l) in the central region and increases toward the lower areas along the Chi River in the west and north, and along Huai Taen Creek in the east and Huai Kut Chuak Creek in the south. Hydrochemical facies changes along the regional flow paths are as follows:

$Ca\text{-}HCO_3 \rightarrow Ca\text{-}HCO_3\text{-}Cl \rightarrow Na\text{-}Cl$ (Central to eastern regions)

$Ca\text{-}HCO_3 \rightarrow Ca\text{-}Na\text{-}HCO_3 \rightarrow Na\text{-}Cl$ (Central to western regions)and

$Ca\text{-}HCO_3 \rightarrow Ca\text{-}HCO_3\text{-}Cl \rightarrow Ca\text{-}Na\text{-}HCO_3\text{-}Cl$ (Central to northern regions)

From a general view point, four regions mentioned above deserve detailed investigation of groundwater flow regimes. Unfortunately, the northeast region (Nam Phong) is a military reserve and is inaccessible. Therefore, plans was made to conduct detailed hydrogeologic mapping in the areas of Huai Yai, Chonnabot and Hin Tank. Significantly, the boundaries among these areas have to be examined in order to delineate their groundwater flow regime. Prior to conducting detailed investigation in the regional areas, an experimental site was chosen to perform a pilot experiment to examine the boundary condition, and to evaluate the relationship among groundwater flow regime, surface manifestations, hydrochemistry and origin of the saline water. The site chosen for this project is Ban Nong Khai Nun. It is located about 12 km south of the Town of Khon Kaen (Figure 1.1b). The hypothesis was postulated that the major rivers, i.e., Chi and Phong rivers may have developed along the fault lines and/or zones. The zones may act as permeable either impermeable boundaries in controlling groundwater flow in the Khon Kaen Drainage Basin.

3.2 Ban Nong Khai Nun

3.2.1 Introduction

Salient surface manifestations, soap holes, flowing wells, major streams, saline soils, and salt tolerant plants, are commonly found in the paddy field at Ban Nong Khai Nun. The relatively high pumping rates (greater than 50 l/s after Wongsawat et al., 1989) have been utilizing groundwater from the Phu Tok Formation in the vicinity of 2 to 3 km west and southwest of Ban Nong Khai Nun. For these reasons, Ban Nong Khai Nun was selected for conducting an experimental site for the small scale in order to identify some hydrodynamic processes and boundaries of groundwater regime, to examine the possible origins of saline soil and soap holes, to characterize the degree of heterogeneity of aquifers, to correlate surface manifestations to groundwater flow systems, and to apply the technique for the regional scales of hydrogeologic mapping in the Khon Kaen Drainage Basin. Ban Nong Khai Nun, which comprises an area of about 9 km^2, is situated in the northern part of Hin Tank area located in the southeast region of the Khon Kaen Drainage Basin (Figure 1.1b).

3.2.2 Groundwater levels

Non-pumping water levels and chemical compositions of groundwater in the following wells: WW4, P5, P85, P84, P83, P82, WW19, P81 and P76 at Ban Nong Khai Nun and Ban Don Bom, were monitored monthly for a period of 12 months (Table 3.4). The observed groundwater levels in Ban Nong Khai Nun area provide a potentiometric surface map and hydrogeologic profile throughout the area as shown in Figures 3.12 and 3.13.

3.2.3 Pumping tests

A long term pumping test was carried out in well WW4 with 14 observation wells as shown in Figure 3.13. A preliminary pumping test was conducted for 30 to 60 minutes prior to the main test, in order to set the appropriate pump rates. Pumping rate and water levels in both pumping wells and observation wells, were recorded manually. There are various specialized purposes for conducting pumping tests, namely: determination of aquifer properties i.e., hydraulic conductivity, storativity and anisotropy of aquifers; and the possible identification of boundary conditions for the groundwater flow regime i.e., faults and joints.

For the pumping test in WW4, pumping started at 10 am on 20 July, 1989, ended at 8:25 am on 23 July, 1989. The duration of pumping was 93 hours and 35 minutes; depth of wells: 131.1 m; size of well 196 mm (8 inches); bottom of casing set at 24.38 m; screened at 24.38 to 36.57 m and open hole from 36.57 to 131.1 m; a turbine pump was set at 18 m; non-pumping water level: 0.16 m below the ground surface; maximum depth to water during the test: 5.28 m; average pumping rate: 44.64 l/s (708 US gpm). Water levels observed in pumping well (WW4) and 14 observation wells: WW3, P1, P2, P3, P4, P5, P6, P7, P85, P84, P83, P81, P82 and WW19. These observation wells partially penetrated the aquifer and the geometric factors of these wells are tabulated in Tables 3.6a and 3.6b. The detailed water-level measurements of this test are included in Appendix 3.1.

3.2.3.1 Interpretation of aquifer tests.

Match point quality between time-drawdown curve and type curves ranges from uncertain to excellent for the first three log cycles adjusted drawdown curves; match quality is dependent partially on data quality. Early data has the greatest uncertainty because: (1) people taking measurements initially were inexperienced, (2) early measurements came in short time intervals, (3) early water-level changes were close to measurement accuracy limits, and (4) early pumping rates probably were greater than the long-term average rate. Due to these uncertainties, the later part of the time drawdown curve of the observation well data shows a better fit curve in every observation well. (Figure 3.14a to 3.14h). The input and output parameters are tabulated in Table 3.6a.

The results of analyses of pumping tests of the observation wells that were affected by pumping well WW4 indicate horizontal hydraulic conductivities (Kr) and vertical hydraulic conductivities (Kz) ranging from 2.22E-05 to 5.83E-05 m/s and 8.03E-05 to

1.03E-04 m/s respectively (Tables 3.6b). The ratio of vertical hydraulic conductivities to horizontal hydraulic conductivities (Kz/Kr) range from 0.07 to 0.3. Storativity (S) of the aquifer ranges from 5.05 x 10^{-4} to 5.1 x 10^{-2}. Moreover the ratio of horizontal hydraulic conductivity (Kr) to vertical hydraulic conductivity for the aquitard (K') exceeds 100. Thus groundwater flow in the aquitard is vertical and in the aquifer is horizontal and directed radially toward the pumping well. These analyses are valid for a leaky, anisotropic aquifer system and are therefore relevant to the sandstones, siltstones and shales of the Phu Tok (Tpt) and Mahasarakham (Kms) hydrogeologic units.

The magnitude and direction of horizontal hydraulic conductivity (Kr) are plotted spatially in Figure 3.12. Two main directions of Kr are: the maximum hydraulic conductivity (Kx) and minimum hydraulic conductivity (Ky). Kx between P6 to WW4 and WW4 to P3 is oriented northwest to southeast (between P5 to WW4). The direction of Ky is aligned northeast to southwest. The magnitude ratio of Kx to Ky is approximately 1 to 5. The Phu Tok unit is an heterogeneous and anisotropic aquifer.

The Theis-Hantush method requires that the pumping time should be of sufficient duration (Boonstra, 1992). For the pumping test in well WW4 the Theis-Hantush method was applied by using the code TYPE7 (Dowson and Istok, 1991). The well functions for partial penetration of each observation well were calculated with a pumping time of 5610 minutes (93.5 hours) until no further drawdown can be observed in the pumping well (WW4). It is believed that the pumping duration is sufficient to yield reliable results. Water samples were periodically collected for chemical analysis. There was no change in the chemical compositions of pumped water over the course of the test during the pumping operation.

3.2.3.2 Effects of concealed faults on flow systems

The potentiometric surface of groundwater in Figures 3.13 and 3.15 indicates that groundwater flows from the south towards the central region where the flowing wells occur in the paddies of Ban Nong Khai Nun. The salient feature of the equipotential lines is the sudden drop of water levels (5 m) immediately across Huai Chan Creek.

From these observations two hypotheses were set up: first, regional geologic structures (faults, joints and folds) may play a significant role in controlling the characteristics of natural groundwater flow patterns and second, fracture permeability is a controlling factor in the origin and distribution of soap holes in a discharge area.

Figures 3.16a to 3.16c show the changes in water levels related to the pumping levels (drawdown), at specified times during the pumping period of the pumping well WW4 and records and observations of water levels in the other 14 observation wells. The cone of depression that developed around WW4 during the pumping test is elliptical in plan view, the long axis oriented in a northwest to southeast direction (Figure 3.15c). After 5000 minutes of pumping, the cone of depression extended over the entire area of a semicircle north of the pumping well (WW4) with a radius over 1000 m. However to the northeast of WW4 (across the Huai Chan Creek between P5 and P85), no changes in water level were observed in the piezometers in the northern region of the Huai Chan Creek. This indicates poor hydraulic connection between the northern and southern blocks of the Huai Chan Creek. The steep water level changes are observed parallel to the course of the Huai Chan Creek.

The conclusions that can be drawn from the above observation are: firstly, the Huai Chan Creek and/or the Chi River developed along fault zones. The fault zones were sealed with clay minerals and compressed and act as barrier boundaries for groundwater flow. Thirdly, the area adjacent to the fault zones are still permeable. This may be due to the flushing by groundwater discharge manifest by flowing wells existing in this area and the formation of cavities along the bedding planes developed due to later deformation.

These phenomena were confirmed by the pumping test results at Ban Nong Khai Nun and subsurface televiewer investigation in P1 as depicted in Plates 3.3. The highly permeable rocks (fractures and cavities), therefore, developed parallel to both the strike of the Phu Tok unit and to the fault lines. This highly fractured zone may focus upward flow and it is a favorable location for soap hole occurrences as shown in the sketch diagram in Figure 3.17.

3.2.4. Surface manifestations

Salient manifestations are: flowing wells, soap holes, salt tolerant plants and saline soils that commonly appear at the ground surface in the vicinity of the paddy field (Figure 3.12).

3.2.4.1 Flowing wells

The flow of water in a well may be due to one of two reasons (Tóth, 1966a). Firstly, the well penetrates an aquifer in which the upward movement of the water is confined by an aquiclude, and in which the pressure head is higher than the distance between the top of the aquifer and the land surface (confined flow). Secondly, in an homogenous geologic environment with downward gradually increasing fluid potential the well penetrates to a point where the hydraulic head exceeds the surface elevation of the well (unconfined flow). The distribution of flowing wells in an unconfined flow system is controlled by the topography.

There are four flowing wells in Ban Nong Khai Nun area namely, WW4, P2, P3 and P4 as shown in Figure 3.12 and Plates 3.4 and 3.5. Non-pumping water levels at these wells were measured by extending a vertical pipe upwards from the well head. Flowing wells are interpreted as points of groundwater discharge. Whether they represent discharge from a confined aquifer or are caused by upward-moving unconfined systems are decided on the basis of additional observations.

3.2.4.2 Soap holes

A soap hole was described by Tóth (1966b) as "*a part of the land surface characterized by a local weakness of limited extent underlain by a viscous mixture of sand, silt clay and water.*" Clissold (1967) described the location where a part of the land surface is characterized by a local weakness resulting from an excessive pore-water pressure.

In the paddy fields at Ban Nong Khai Nun, sixty-two soap holes were mapped as illustrated in Figure 3.12 and Plates 3.6 and 3.7. These weakened areas are commonly circular to elliptical in plan view with well-defined boundaries. Their depths vary from 0.5 to 3 m below the ground surface and the circular to elliptical boundaries vary from 3 m to 20 m in diameter. A typical soap hole is covered by a thin, fragile crust, compact substrate. Calcretes and ferrugenous nodules are commonly associated. The lack of solid support below the land surface is indicated by a springy vibration of the surface at and around the holes when the ground is stamped upon. The crust is commonly barren (Plates 3.5 3.6 and 3.7). The upward flow of water in sand under a critical hydraulic gradient that renders the effective stress equal to zero produces quick sand (Rutledge, 1940).

Archwichai et al. (1985) collected fourteen samples of soil and clay in the soap holes at Ban Nong Khai Nun to test for pH and clay mineralogy. The pH values of the mud in these soap holes range from 8.90 to 9.50 which are alkaline. The ground surface of the soap holes is composed of calcite (60-70%) and quartz (20-25%) with minor fractions of feldspars, dolomite and clay minerals. Wongsomsak (1986) found abundant montmorillonite in the pores of the sandy material during an active period of the soap holes.

The soap holes are aligned along two trends: northwest-southeast (parallel to the Huai Chan Creek) and northeast-southwest (parallel to Chi River), (Figure 3.12). These soap holes are interpreted as focused discharge in moving groundwater (the discharge area) from the Hin Tank area that is located in the south. At Ban Nong Khai Nun groundwater flows through relatively low permeability siltstones and shales of the Phu Tok unit and through local high permeability rocks that were sheared and deformed by faulting and folding along axes oriented both northeast-southwest and northwest-southeast as shown in Figure 3.17.

3.2.4.3 Salt precipitates and saline soils

Salt precipitates are a whitish, light gray color in dry weather. The dissolved matter precipitates, commonly leaving a noticeable coating of mineral salts on the previously wetted surfaces. These salt crusts consist of interlocking botryoidal shaped salt crystals. NaCl is the dominant soluble salt found in the Khon Kaen area (Patcharapreecha et al, 1989). Salt patches and halophytic vegetation can be observed in the Dry Season around soap holes, where the depth to the water table is less than 0.5 m (Plate 3.8).

The saline soils at Ban Nong Khai Nun are well weathered sandy textured soils with a low capillary exchange and low organic content (Patcharapreecha et al., 1989). Topark-Ngarm et al. (1990) found that not only the salt but also the clay minerals moved upward due to the capillary movement and downward due to the percolation of the rain water within the unsaturated zones. The salts in the groundwater moved up and accumulated on the soil surface in the dry season. Na-Clay (or organic matter) and HCl were formed by a process of cation exchange between NaCl in the groundwater and H-Clay, resulting in the reduction of the pH in the following reaction: H-clay + NaCl → Na-clay + HCl. During the rainy season, rainfall water leached the salts in the soil and released the cations adsorbed on the clay (or organic matter) surface. The released NaOH increased the pH, as: Na-clay + H_2O → H–clay + NaOH. The soil contains large amounts of dispersible clay in the Rainy Season, but small amounts in the early Dry Season. FeS dissolved in the groundwater was considered by Topark Ngarm et al. (1990) to be an acidification agent, as it became oxidized to ferric hydroxide and sulfuric acid when drawn up to the soil surface by capillary movement.

3.2.4.4 Natural vegetation

Vegetation consists of sparsely distributed halophytes and phreatophytes. Five dominant plant species found in Ban Nong Khai Nun, were identified by Homchuen (1990), *Azima sarmentosa* (Nam Pong Do, Thai name, Plate 3.9), Maytenus mekong genesis (Nam Daeng, Plate 3.10), *Gisekia pharmacoides* (Pak Bia Daeng, Plate 3.11), Synostemon bacciformis (Soy Nok Kao or Ma Fai Doen Ha, Plate 3.11) and Massia triseta (Yar Hua Kai, Plate 3.11). *Azima sarmentosa* is commonly found in the vicinity of soap holes and *Fimbristylis Hookeriana* (Yar Hua Bo) are also found in swampy areas, Plates 3.6 and 3.7). The ground covered by these plants ranges from about 1 to 2%; maximum plant height rarely exceeds 2 m. *Gisekia pharmacoides* grows in the highly saline soil and on the surface of the dry and puffy soap holes. These plants exhibit high salt tolerance (halophytes) and grow in discharge areas and areas of shallow water table. *Gisekia pharmacoides* is probably phreatophytic meaning that it habitually obtains its water supply from the zone of saturation either directly, or through the capillary rise (Meinzer, 1923).

3.2.5 Hydrochemistry

The conceptual groundwater flow model, is based on the measured hydraulic head values shown in Figure 3.15, however some aspects on hydrochemistry attributable to flow systems can be discussed here. Total dissolved solids contents (TDS) of groundwater in Ban Nong Khai Nun (Figure 3.18) vary from 170 mg/l to more than 33,000 mg/l. Three distinct TDS zones can be differentiated: first, in the Phu Tok unit (southern region), the TDS contents increases from 550 mg/l in the deeper layer at WW4 to 1160 mg/l in the shallower part at P5. The TDS content is increasing in the direction of flow (i.e., as the hydraulic head decreases). Second, in the central region located between the Huai Chan Creek and Chi River, TDS contents in alluvium deposits and in the Mahasarakham unit generally increase downward from 170 mg/l to greater than 30,000 mg/l. Third, in the northern region of the Chi River, groundwater exhibits relatively high TDS contents, greater than 30,000 mg/l. This area is a part of the discharge area of the Nong Lup regional flow system in the Huai Yai Hydrogeologic Province that is identified in Chapter 4. In the Kms unit Mg^{2+} : Ca^{2+} molar ratio increases along the flow path from less than 0.1 to greater than 0.6 (Figure 3.19). In both the Phu Tok and Mahasarakham units Ca^{2+}: Na^{+} molar ratio is decreasing along the flow path from greater than 1.0 to less than 0.1 (Figure 3.20). The effects of hydrochemistry, distributions of TDS, Mg^{2+} : Ca^{2+}, and Ca^{2+} : Na^{+} agree with Chebotarev's sequence (1955) along the flow paths of 500 m to 20 km in length.

Hydrochemical facies were identified using Piper diagrams modified by Galloway and Kaiser (1980) as shown in Table 3.4a. When rain water infiltrates into sand, silt and clay of Quaternary alluvium (Qal) it is rapidly transformed to groundwater with the Ca-HCO_3 facies, which then flows downward into sandstones, siltstones and shales of the Kms unit where the Ca-Na-HCO_3-Cl facies develop. The groundwater ultimately evolves into Na-SO_4-Cl and Na-Cl facies at the discharge end of the flow systems (Figure 3.21). It is clearly seen from the geologic section that the source of salt is the halite beds in the Mahasarakham unit. Discharging groundwater is the main mechanism for salt distribution since the NaCl content of the rain water recharge is low and NaCl content of groundwater along the flow path becomes extremely high TDS contents only when it passes through a halite zone. Saline soils at the ground surface are found where the flow path is ascending and also where the spatial variations in hydraulic conductivities produce a flow convergence (Figure 3.17).

The Na^{+}:Cl^{-} molar ratio (Table 3.5) also shows a trend towards 1.0 with increasing TDS content further suggesting that halite dissolution is the major source of salinity. In some areas such as P84 Na^{+}:Cl^{-} molar ratio exceeds unity rising to about 4.0. Such exceptionally high Na^{+} content may be due to the leaching of Na-rich clay minerals (montmorillonite) in the alluvial sediments. The chemical reaction here may be approximated as : Na-clay + $H_2O \rightarrow$ H–clay + NaOH (Topark-Ngarm et al., 1990). There is a corresponding decrease in $Mg^{2+}:Cl^-$, $Ca^{2+}:Cl^-$ and $K^+:Cl^-$ molar ratios with increasing TDS contents.

The isotopic composition of water is expressed in comparison to the isotopic composition of ocean water. For this purpose an internationally agreed sample of ocean water has been selected, called Standard Mean Ocean Water, or SMOW (Craig, 1961). The isotopic composition of water, determined by mass spectrometry, is expressed in per mil (°/₀₀) deviations from the SMOW standard. These deviations are written of δD for the deuterium, and $\delta^{18}O$ for ^{18}O:

$$\delta D\ ‰ = \frac{(D/H)_{sample} - (D/H)_{SMOW}}{(D/H)_{SMOW}} \times 1000$$

and

$$\delta^{18}O\ ‰ = \frac{(^{18}O/^{16}O)_{sample} - (^{18}O/^{16}O)_{SMOW}}{(^{18}O/^{16}O)_{SMOW}} \times 1000$$

Willamson et al. (1989) analyzed the stable oxygen and hydrogen isotopic compositions of rainfall in the Khorat region located about 180 km south of the Khon Kaen Drainage Basin. They found that the local meteoric water line is:

$$\delta D = 7.78\delta^{18}O + 8.6$$

This local meteoric water line is close to the World Meteoric Water Line $\delta D = 8\delta^{18}O + 10$ (Craig, 1961) as shown in Figure 3.22a. Table 3.2a shows that the ranges of delta values for deuterium in rainfall within the Khon Kaen Drainage Basin are -39 and-48°/₀₀ (parts per thousand). The delta value of recharge groundwater at P84 is -51 °/₀₀ which falls in the range of the delta value for precipitation at this latitude. This is clear evidence that the source of recharge to groundwater is rain water.

The deuterium and oxygen-18 contents of groundwater in the Phu Tok unit are -59 °/₀₀ and -7.9 °/₀₀ respectively. Stable isotope signature of groundwater in the

Mahasarakham unit is similar to that of the Phu Tok Formation (-48 to -61 °/₀₀ for deuterium and -2.8 to -7.7 °/₀₀ for oxygen). The $\delta^{18}O$ values of groundwater from different flow systems are distinct. The $\delta^{18}O$ of wells P5, (-7.9 °/₀₀, in the southern region, Huai Toei regional system (see Chapter 4) and P83 (-7.7 °/₀₀ in the northern regions, Nong Lup regional system), are significantly lower than the $\delta^{18}O$ of wells P84 and P85, -5.70 to -6.10 °/₀₀ in the central region (Tha Phra local flow system). This is due primarily to the differences in elevations of the recharge areas of the local versus the regional flow systems, providing that a linear relationship between the $\delta^{18}O$ value and the mean yearly surface air temperature exists (Wallick and Tóth, 1975). Whereas, at P82, the $\delta^{18}O$ is relatively high (-2.8 °/₀₀). This may be due to the mixing of ground and surface water from the Chi River. It is difficult to differentiate groundwater flow systems based solely on hydrochemistry in the areas in which the groundwater flows through evaporite zones. However, it is possible to identify local and regional flow systems by using stable isotopic compositions.

The relationship between deuterium and oxygen delta values for the groundwater in the Mahasarakham unit, plot to the right of the local meteoric water line. This indicates that evaporation may significantly affect both recharging and discharging groundwater. The plots of oxygen and deuterium delta values versus total dissolved solid are shown in Figures 3.22b and 3.22c respectively. With increasing salinity (TDS content) there is no significant change in oxygen and deuterium delta values (see data points of P84 to P85 and P81 in Table 3.4). This suggests that the increased salinity at these locations may be due to the dissolution of salt in the evaporites of the Mahasarakham Formation (Gat and Gonfiantini, 1981).

3.2.6 Conceptual and numerical groundwater flow model at Ban Nong Khai Nun

3.2.6.1 Conceptual model

The monthly water levels in wells and piezometers are divided into three groups based on the three seasons, namely, Summer Season (March to June), Rainy Season (July to October) and Winter Season (November to February). Each group of water levels represents the average water levels of each season as shown in Figure 3.23.

The most likely explanation for the observed hydraulic anomalies and water-quality pattern is the occurrence of fractured zones caused by faulting. Theoretically, intense deformation at the intersection of faults enhances the development of conduits that allow the upward migration of high-chloride water. Fracturing in the Khon Kaen Drainage Basin is due to the faulting and folding of competent and incompetent strata. Both horizontal and vertical displacements occur in the en echelon and strike slip faults in this region (Figure 3.15). Whether fractures actually function as hydraulic conduits or not depends on the extent to which they are sealed by subsequent mineralization. Clay minerals are the most common fracture sealing material. Some conclusions can be made as follows:

1) Water levels in wells near the Chi River (P83, P82, P81, WW19 and P76) are higher in the Summer and Winter Seasons than the water level of the Chi River itself. In the Rainy Season, however the water levels in these wells are relatively lower than the water level of the Chi River.

2) The Chi River can be characterized as an effluent stream which discharges water to the aquifer during the Rainy Season (July to October, Figure 3.24a). During the Winter and Summer Seasons, on the other hand, it becomes influent and receives water from the aquifer (November to June, Figure 3.24b).

3) Prior study of the Khon Kaen Drainage Basin indicates that groundwater is discharging at the Chi River on a regional scale. The Chi River water comprises of mixed

groundwater from two converging flow systems (Huai Yai area located in the northern region of the Chi River, and Hin Tank area from the southern region (Figure 6.3)).

4) A local recharge area exists in the central region as indicated at P84 despite the flat, featureless topography. The flow system in this area is controlled by a concealed fault along the Huai Chan Creek and the Chi River. The total dissolved solids content of groundwater in P84 (170 mg/l) is much less than that in other wells (650 to 33,000 mg/l). Both hydraulic and chemical groundwater data in P84 therefore provide supporting evidence that this area is a local recharge site, discharging to the nearby the Chi River and to Huai Chan Creek. The diagrammatic representation of the conceptual groundwater flow at Ban Nong Khai Nun related to surface manifestations is depicted in Figure 3.25.

Several physico-chemical surface manifestations of groundwater flow were mapped at Ban Nong Khai Nun. Those phenomena which are soap holes, salt precipitates and salt tolerant vegetation are good surface manifestations of a discharge area.

3.2.6.2 Numerical model

The purpose of the computer modeling is to refine the understanding of the influence of groundwater flow on salinization. A three-dimensional steady-state finite difference equipotential model was used for simulating groundwater flow within Ban Nong Khai Nun. The simulations were conducted using MODFLOW. Stoertz and Bradbury (1989) described a computerized water budget method that calculates the spatial distribution of recharge and discharge rates given a water table contour map. The method can be used with any model that calculates fluxes between specified head nodes as a part of water balance. MODFLOW does not calculate these fluxes and modifications to the program that were made by Stoertz and Bradbury (1989) were necessary to use the method resulting in table 2.1.

The coupling procedure uses a regional simulation (Hin Tank Hydrogeologic Province see Chapter 6) to approximate the water budget for the sub regional area (Ban Nong Khai Nun); that is, it computes the quantity and distribution of flow to both the natural and artificial boundaries in the sub regional area. Water crossing the artificial boundaries of the sub region is derived from natural boundaries or storage outside the area. Conservation of the volume of water within the entire system and within the sub region is maintained by the regional simulation. This technique is called *telescopic mesh refinement* (Ward et al., 1987). For steady-state conditions, the regional model simulates the hydrologic condition of interest to provide a coarse-scale estimate of groundwater levels within the system. The results are then used to calculate the distribution of fluid flux, block by block, across the artificial boundaries of the sub region. The flow from each regional block is divided among the corresponding smaller blocks along the sub region boundary. The coupled regional-sub regional simulation is then made from the sub regional representation with the specified-flow boundary conditions predicted by the regional model. In transient-state simulation, the procedure must be applied for each time step of simulation. The details of the procedure were explained by Buxton and Reilly (1986), and Anderson and Woessner (1992).

The groundwater flow system was modeled at Ban Nong Khai Nun. The lower boundary for the model was set at the elevation 0.0 m above mean sea level. Fixed hydraulic heads or flux across the grid blocks for the north, east, south and west boundaries were taken from the results of simulations of the regional flow model of the Hin Tank Hydrogeologic Province (Chapter 6). The water table was defined using measured head values that were assigned to the upper boundary. The Huai Chan Creek and Chi River are treated as no flow boundaries.

The area was discretized into rectangular grid blocks (32 grid blocks north-south, and 30 grid blocks east-west and 16 vertical layers. Each rectangular block represents 100 m and 10 m in horizontal and vertical scales respectively as shown in Figures 3.26a and 3.27.

Assigned hydraulic conductivity values for the sands, silts and clays of alluvium sediments (Qal), sandstones, siltstones and shales of the Phu Tok (Tpt) and

Mahasarakham (Kms) hydrogeologic units are tabulated in Table 3.7. The hydraulic conductivities of aquifers in the x and y directions are assumed to be isotropic, whereas the vertical hydraulic conductivities are assigned values about one to two orders of magnitude less than the horizontal conductivity.

Calibrations and adjustments of the hydraulic conductivities of the aquifers were attempted until the calculated hydraulic heads replicated the observed hydraulic heads at the reference piezometers as shown in Figures 3.28. The differences between calculated and measured hydraulic heads range between less than 1 m to 3.2 m. Therefore the final results of simulated hydraulic head distribution are presented in Figures 3.26a and 3.26b.

The results of simulations support the earlier statement that the groundwater discharging at the salinised area is derived from distinct regional and local flow systems. The horizontal and vertical fluxes were calculated and plotted by the MODGRAF Module version 4.4 (Tecsoft 1992) as shown in Figures 3.27a and 3.27b. The positive and negative values of the flux represent recharge and discharge to the ground surface respectively. The local recharge rates at the central region (P84) range from > 0 to 2.31E-05 m/s as well as discharge rates (Figures 3.28 and 3.29).

The modeling results yield realistic patterns of recharge rates which compare well to piezometric calculation (1.16E-09 to 3.47E-07 m/s) based on an assumed specific yield of rock of 0.1. These results from the model calibration suggest that horizontal hydraulic conductivities of the Phu Tok unit are higher than the vertical hydraulic conductivities. Moreover, the horizontal anisotropy (Kx:Ky) of the Phu Tok Formation ranges between 1:1 to 5:1 that are similar to the Kx:Ky ratio from the pumping test analysis in section 3.2.3.1.

3.2.7 Effects of hydrochemistry and soil salinity on flow systems

Salinity problems may develop given sufficient sources of salt and water and a suitable mechanism for salt distribution. Analysis of groundwater flow patterns and flow systems integrated with geomorphology and soil science are powerful tools for identifying the possible mechanisms of saline groundwater formation and the resulting pattern of soil salinity (Pawluk, 1983, Maclean, 1974 and Stein and Schwartz, 1990).

Soil salinization patterns at Ban Nong Khai Nun are clearly related to groundwater flow in the sands, silts and clays of Quaternary deposits (Qal) of the Chi River, and in the sandstones, siltstones and shales of the Phu Tok (Tpt) and Mahasarakham (Kms) units. The distribution of observed flow-related manifestations of hydraulic heads, and of hydraulic conductivity values (based on pumping tests) for the aquifers at Ban Nong Khai Nun area, indicate that both local and regional groundwater systems are the main agents that carry the high salinity water to the discharge areas. There are four possible mechanisms contributing to the occurrence of salinity at the ground surface.

1) Regional groundwater flow (Nong Lup regional system) driving groundwater through the evaporite beds of the Mahasarakham unit with upward discharge at the northern region of the Chi River (faulted boundary). This regional flow path is approximately 15 to 20 km long (Chapter 4). In the central region, the area south of the Chi River and north of the Huai Chan Creek, a local flow system (the Tha Phra local system, Chapter 6) receives rain water in the central area and flows downward dissolving the evaporite beds. Consequently the highly mineralized groundwater is moved upwards by vertical discharge near the Chi River and Huai Chan Creek, which are the faulted boundaries of this local flow system. This flow path is approximately 500 to 600 m in length. The saline soil on the surface is caused mainly by the precipitation of dissolved evaporite minerals from the Mahasarakham unit. The upward movement of the discharging groundwater is conclusively supported by the hydrochemistry and stable isotope distributions.

2) In the southern area of Ban Nong Khai Nun, rain water infiltrates through sandstones, siltstones and shales of the Phu Tok unit and discharges upward at Ban Nong Khai Nun. Along the flow path the total dissolved solids content increases and high

mineralization is observed in the soil of the paddy field where the groundwater flow is focused into the high permeability zones.

3) Redistribution of saline soil at the ground surface near the Chi River may be caused by reverse seasonally flow of effluent and influent stream during the Rainy Season (July to October) and the Winter and Summer Seasons (November to June) respectively.

4) Saline water moves upward from the water table to the land surface where the groundwater level is less than 0.5 m moving through the capillary fringe by evaporation and/or evapotranspiration.

3.3 Discussion

The field investigations of groundwater flow regimes in Ban Nong Khai Nun are valid for several different approaches. Several integrated approaches (field and theoretical) are invaluable tools in quantifying groundwater regimes. Several conclusions can be drawn from the study as follows:

1) regional geologic structures (faults, joints and folds) as well as topography play a significant role in controlling the pattern and intensity of natural groundwater flow,

2) fracture permeability is a controlling factor in the origin and distribution of soap holes (pimple mounds) in a discharge area,

3) recharge and discharge areas are consequences of major rivers and also coincide with fault lines or fault zones,

4) increasing TDS contents and $Mg^{2+}:Cl^-$ and decreasing $Ca^{2+}:Cl^-$ in groundwater along the flow paths both local and regional flow systems are typical of the Chebotarev's sequence,

5) the main source of recharge water for aquifers is precipitation,

6) the major sources of saline water are the ascending groundwaters that percolate through rock salt beds of the Mahasarakham Formation unit. Redistribution of saline water at the ground surface in the lowland areas moves upward from the water table through the capillary fringe by evaporation and evapotranspiration.

7) Numerical simulations of recharge and discharge patterns, and the recorded rates are in good agreement with the field mapping. The significance in simulating a steady-state flow system is the location and type of boundaries and distribution of hydraulic conductivities (fracture patterns) of aquifers and aquitard.

8) A groundwater flow system is characterized by boundary types, porous medium, flow pattern, volume of flow and hierarchical place. The system approach tries to define the complex entity and to explain its internal processes with their cause-and-effect relationships. The analysis of groundwater flow systems based on field mapping of surface manifestations, hydraulic and hydrochemical data is corroborated by the results of numerical modeling.

To apply the field techniques and theoretical approaches for delineating groundwater flow regimes in the Khon Kaen Drainage Basin, the specific type areas, or hydrogeologic provinces, Huai Yai, Chonnabot and Hin Tank, were selected for detailed study including: hydrogeologic mapping and distributions of regional groundwater flow patterns and systems, hydrochemistry, and mathematical models within these type areas that are presented in Chapters 4, 5 and 6.

Chapter 4: Groundwater flow in Huai Yai Hydrogeologic Province:

A broad anticlinal-synclinal province

4.1 Location and topography

The Huai Yai Hydrogeologic Province is situated between latitudes 16°15' and 16°35' N, and longitudes 102°30' and 102°60' E covering approximately 830 km². It extends 21 km from north to south and 43 km from east to west (Figures 1.1 and 4.1). The land surface forms predominately elongated hills (Phu Meng Ridge in the west) undulating terrain at high elevations of 190 to 230 m amsl, rolling hills or undulating terrain at the elevations between 170 to 190 m amsl and flat, low lying flood plains at lower elevations of 150-190 m amsl with the average regional slope across the province of between 0.0007 and 0.002 (Figures 4.2, 4.3 and 4.8).

4.2 Geology and hydrogeologic units

The Huai Yai Hydrogeologic Province is underlain by a series of sedimentary rocks of the Khorat group and covered with a thin veneer of Quaternary sediments. The area's hydrogeologic units are illustrated in Figure 3.2 (Hokjareon, 1986). Lime conglomerates of Triassic Huai Hin Lat (Thl) and Nam Phong (Tnp) Formations, and siltstones, shales and sandstones of Jurassic Phu Kraduang (Jkp) were deposited in the western region, and subsequently overlain by siltstones and sandstones of Phra Wihan (Jpw) and siltstones interbedded with shales of Sao Kua (Jsk) Formations. During the lower Cretaceous, conglomeratic sandstones of the Phu Phan (Kpp) were deposited conformably on the Phra Wihan Formation (Jpw). The Phra Wihan, Sao Kua and Phu Phan formations form an elongated ridge called the Phu Meng in the west. These Formations were deposited with a strike in N-S and dip of 5 to 10° E. Siltstones and shales of Khok Kruat (Kkk) and shales and evaporite beds of the Mahasarakham (Kms) Formations have been overlain by the Kpp unit. The Kkk and Kms form a rolling and undulating topography and imposed upon a broad syncline (Ban Muang) and anticline

(Khon Kaen University campus) with an axis oriented NNW to SSE and plunging to SE as shown in Figure 4.1. This unit forms an elongated hill topography of the Nong Lup Ridge in the north and undulating terrain in the west of Amphoe Ban Fang. During the late Quaternary to Recent, laterite and loess deposits formed extensively in the relatively high to moderate elevations. Sand, silt and clay sediments (Qal) of the Chi and Phong rivers covered in the east and southeast of the province.

The Huai Yai Hydrogeologic Province is areally bounded by the Phu Meng and Nong Lup ridges to the west and north sides respectively, the Chi River to the east, and its perennial tributary, the Na Klang Creek to the south. The streams were developed along the regional faults. The four main areal boundaries create vertical boundaries (groundwater divides) beneath the ridges and valleys across which there is no flow.

The major aquifers in the Huai Yai Hydrogeologic Province are: conglomeratic sandstones of the Phu Phan unit (Kpp), shales interbedded with siltstones and sandstones of the Mahasarakham unit (Kms), sand and gravel unit (Qsg). Figures 4.1 and 4.2 and 4.3 show the distribution of the major aquifers throughout the province and across the hydrogeologic profiles H1-H1' and H2-H2' respectively.

The conglomeratic sandstones of the Phu Phan unit (Kpp) is conformably overlain by the Sao Kua (Jpk) unit which is approximately 80 m thick. It forms the ridge of the Phu Meng. The horizontal and vertical hydraulic conductivities of this unit determined from the pumping test in well WW1 at Ban Khok Kwang is 3.70E-06 m/s and 1.11E-08 m/s respectively (Table 3.1).

In the eastern region of the Phu Meng Ridge, an outcrop of the Khok Kruat unit (Kkk) consists of white to reddish brown micaceous quartz sandstones and fine conglomerates in the lower section, grading to purple to greenish gray siltstones. Lenses, stringers and crystals of gypsum and anhydrite are found in the middle to upper section. The thickness of the unit is approximately 200 m. Its horizontal and vertical hydraulic conductivities represented by well PWTW are 5.79E-07 and 1.16E-10 m/s respectively and the well yield is about 0.3 l/s. This unit is considered to be an aquitard and is conformably overlain by shales interbedded with siltstones and sandstones of the Mahasarakham unit (Kms), and locally unconformably overlain by sand and gravel unit (Qsg).

The Kms unit consists of grayish green to reddish brown shales interbedded with siltstones and sandstones in beds up to 20 m thick, with thickness of 50 to 1000 m. Permeability characteristics in the shales of the Kms unit, were derived from chip samples from rotary drilling water wells, and observation of fractures in the construction pits in the vicinity of the Town of Khon Kaen and lost circulation of drilling mud. The horizontal and vertical hydraulic conductivities range from 1.16E-06 to 8.56E-06 and 1.16E-09 to 8.56E-07 m/s respectively. Well yields in this formation vary between 1.0 and 12.92 l/s. The Kms unit was deposited extensively in the central and eastern region of the province. In the upper section there are three massive evaporite (halite, anhydrite, sylvite and carnallite) sequences varying from 10 to 170 m thick (Japakasert and Suwanich, 1982). The hydraulic conductivity may be relatively low (1.19E-08 m/s, Freeze and Cherry, 1979) and it is considered to be an aquiclude (rock salt unit, rs, in Figure 3.2). The thickness of this unit is non uniform and locally pinches out at the flanks of anticlinal and synclinal structures.

Sand and gravel unit (Qsg) is underlain by the Kkk and Kms units in the Nong Lup Ridges and in the west region of Amphoe Ban Fang. The Qsg unit was deposited and formed elongated hills in the north and west of the province with a thickness of between 2 and 16 m. It is permeable with horizontal hydraulic conductivity in wells PWKS, PWKC and at ARC center ranging from 2.47E-05 to 6.48E-05 m/s. Thin layers of laterite deposits (Qlr) and fine to medium grained sands of Loess deposits (Qls) covered the Qsg unit and formed the undulating terrain. The Qls and Qlr units are clay, silt and sands of alluvium (Qal) which are deposited along the flood plain of the Phong and Chi rivers. The Qlr, Qls and Qal units are grouped as a single hydrogeologic unit (Ql unit) that is considered to be an aquitard.

4.3 Piezometric analysis of regional groundwater flow

Twenty-three piezometers were installed along the hydrogeologic profiles H1-H1' and H2-H2'. The directions of these hydrogeologic profiles were designed to be perpendicular to the regional potentiometric contours which were determined by the reconnaissance survey in Figure 3.5. The purpose of the piezometer installation was to investigate the groundwater movement in various places along the groundwater flow paths. The monthly non-pumping water levels were arithmetically averaged from the records made between May 1989 and April 1990 (Table 4.3). They were used to construct average equipotential lines as illustrated in Figures 4.2 and 4.3. In addition, the locations and boundaries of recharge (R) and discharge (D) were mapped along the profile as well as groundwater flow directions.

4.3.1 Flow patterns along hydrogeologic profiles

4.3.1.1 Hydrogeologic profile H1-H1'

There are 8 piezometers, WW1, P70, P22, WW2, F606, P20, P19 and WW7, installed across the hydrogeologic profile H1-H1'. These piezometers were drilled to different depths into various hydrogeologic units. The equipotential lines derived from the measurements of the average water levels and inferred groundwater flow directions were constructed as illustrated in Figure 4.2. Along this hydrogeologic profile, the major groundwater divides are located at the Phu Meng Ridge (NW) and Chi River (SE). The highest hydraulic head of groundwater (195 m amsl) is at well WW1 (Ban Khok Kwang), whereas the lowest hydraulic head (140 m amsl) is found in the flood plain of the Chi River. Groundwater flows downward through siltstones and shales of the Jpk unit, conglomeratic sandstones of the Phu Phan unit (Kpp) and siltstones and shales of Khok Kruat unit (Kkk) which are located in the recharge area in the west. The groundwater flows laterally across the shales of the Mahasarakham unit (Kms) and flows upward in the area near the Chi River.

The density of the equipotential lines decreases with increasing depth. At the shallow depth, there are several places indicating intervention of recharge and discharge areas such as the areas between Ban Khok Kwang and Ban Muang, and Ban Muang and Ban Sa-Art. The water table generally conforms with the undulating topography; however is more subdued at low elevations.

4.3.1.2 Hydrogeologic profile H2-H2'

Seventeen piezometers tubes, F531, PWNZ, P32, WW11, P73A, P73, P20, P19, WW7, P18, P17, P16, P15, P14, P13, P12 and PWKS, were installed along the hydrogeologic profile H2-H2' as shown in Figure 4.3. The groundwater divides along this profile are located at Na Klang Creek (south), Kaeng Nam Ton reservoir (at the southeast region) and Nong Lup Ridge in the vicinity of Khon Kaen University campus to the north. The hydraulic head decreases from well PWKS and P12 located in KKU campus to Ban Sri Than at P15 and P16 (in the south), and to the brackish water reservoir at the southern gate of the university and towards Ban Kok at Nong Khot reservoir (P17 and P18). Salt crust and a community of salt tolerant plants are found in Ban Sri Than and Ban Kok. Further south at Ban Sa-Art, the piezometer nests P20, P19 and WW7 indicate that the hydraulic head decreases downward from Kaeng Nam Ton reservoir towards the Chi River. Unfortunately very few piezometers are available in the southern region along the profile H2-H2', however the data suggested that the higher hydraulic head in the vicinity of Ban Nong Wang Hi decrease toward Ban Wa (P73 and P73a). Piezometer P73A is a flowing well that represents upward flow. The groundwater also flows radially to Na Klang Creek in the south, Amphoe Phra Yun (the flowing well P32 in the west) and eastward to the flood plain of the Chi River.

The equipotential lines and inferred groundwater flow directions across the hydrogeologic profiles H1-H1' and H2-H2' indicate that groundwater flow across the Huai Yai Hydrogeologic Province is active in three-dimensions.

4.3.2 Flow patterns determined by piezometric analyses in the Huai Yai Hydrogeologic Province

Recharge and discharge areas were mapped based on the measurements of water level in 54 piezometers and wells as shown in Figures 4.2 and 4.3 and 4.4. Figure 4.4 illustrates the distribution of field equipotential lines in the aquifers as well as inferred directions of groundwater flow in plan view. The total surface area of the province, as calculated by the SURFER V.4.0 program (Golden Software, 1989), is approximately 830 km^2 comprising of 270 and 560 km^2 of recharge and discharge areas, respectively.

The highest hydraulic heads in the Huai Yai Hydrogeologic Province are located in the west along the Phu Meng Ridge. There are three main regional groundwater flow directions across the province. Firstly, it flows from the water divide area located along the Nong Lup Ridge to Bun Nong Khot and Kaeng Nam Ton reservoirs in the south. Secondly, it flows from the western regions in the vicinity of the Phu Meng Ridge across the central region of the province to Kaeng Nam Ton reservoir. Thirdly, groundwater flow is active in the vicinity of the Ban Nong Wang Hi located in the southeast and south, flows to the Ban Wa and Bung Kaeng Nam Ton reservoir (Figure 4.4). The configuration of an equipotential surface displays regional hydraulic head gradients decreasing to the southeast. However, the regional hydraulic-head data are insufficiently sensitive to demonstrate the effects of aquifer heterogeneities on flow in the horizontal level.

Cross formational flow is a regionally significant aspect of groundwater movement in the Huai Yai Hydrogeologic Province. The flow paths may be affected by the layered heterogeneity and anisotropy of the strata (Hubbert, 1940). In the Huai Yai Hydrogeologic Province the groundwater encounters rock salt layers (rs unit) interbedded with sandstones and siltstones (K=3.44E-06 m/s) of the Mahasarakham unit (Kms) and flow through high-permeability aquifers which are sub-horizontal or parallel to dip, whereas vertical, cross-strata flow encounters overlying low-permeability layers (such as rock salt unit, rs). Significantly, the hydrogeologic profiles along H1-H1' (Figure 4.2) and H2-H2' (Figure 4.3) show that topography induces cross-formational leakage into and out of the buried high permeability units (Kms and Kpp).

The flow regime in the Huai Yai Hydrogeologic Province indicates that the water table in recharge areas is generally between 5 and 15 m below the ground surface whereas it is less than 1.5 m deep in discharge areas (Figure 4.5). There remain, however, adequate elevation differences to provide the hydraulic gradients described above.

The groundwater flow systems in the Huai Yai Hydrogeologic Province were evaluated based on field observations, water level measurements in both lateral and vertical directions and magnitudes of the flow, boundaries and hydrostratigraphy. The determination of hydraulic parameters of the flow systems in the Huai Yai Hydrogeologic Province have been discussed in Chapters 2 and 7. The results of measurements and estimations of the hydraulic parameters of the flow systems are tabulated in Table 3.1. The distributions of the flow systems are illustrated in Figures 4.2, 4.3 and 4.4. Ten groundwater flow systems are identified as follows:

- Phu Meng regional system (AR1)
  - Ban Khok Kwang intermediate system (AI1-1)
    - Ban Fang local system (AL1-1)
    - Ban Muang local system (AL1-2)
- Nong Wang Hi regional system (AR2)
  - Ban Kham Pom intermediate system (AI2-1)
- Nong Lup regional system (AR3)
  - Ban Sri Than intermediate system (AI3-1)
  - Kaeng Nam Ton intermediate system (AI3-2)
    - Ban Sa-Art local system (AL3-1)

where: A represents the Huai Yai Hydrogeologic Province, R, I and L are Regional, Intermediate and Local flow systems, respectively. An Arabic numeral in its symbol indicates a consecutive number of the flow system.

The identified flow systems in the Huai Yai Hydrogeologic Province comprise three regional, four intermediate and three local flow systems. The significant properties of the following flow systems are summarized in Tables 4.1 and 7.2.

The regional flow systems, Phu Meng (AR1), Nong Wang Hi (AR2) and Nong Lup (AR3) define the limits of the Huai Yai Hydrogeologic Province. The Phu Meng system (AR1) exhibits the longest flow path of 20 to 40 km, and the greatest flow depth of about 155 m measured at the midline areas of the flow system from the profile H1-H1'. The Phu Meng system has an average maximum flux of 7.32E-06 m/s, and the direction of flow is generally toward the east. Nong Wang Hi regional system (AR2) located in the southeastern region has a flow path 10 to 12 km long. Groundwater flows at the maximum depth at the midline area of about 157 m. The Nong Lup regional system (AR3) is active in the northern region. Its flow path is approximately 8 to 12 km in length and its depth is less than 160 m. The groundwater flows mainly from north to south and has an average maximum flux of 1.87E-07 m/s. The three regional systems, AR1, AR2 and AR3, merge with each other and ascend in the regional discharge area at Kaeng Nam Ton Reservoir (Figures 4.2, 4.3 and 4.4).

Ban Khok Kwang (AI1-1), Ban Kham Pom (AI2-1), Ban Sri Than (AI3-1) and Kaeng Nam Ton (AI3-2) are the intermediate flow systems. They are superimposed on the Phu Meng (AR1), Nong Wang Hi (AR2) and Nong Lup (AR3) regional systems respectively (Figures 4.2, 4.3 and 4.4). These intermediate systems exhibit flow path lengths of 20 to 30, 8 to 10 and 5 to 8 km with flow depths of approximately 60 to 100 m.

The three local flow systems, Ban Fang (AL1-1), Ban Muang (AL1-2),and Ban Sa-Art (AL3-1) have 0.5 to 3 km long flow paths, and occur in the relatively shallow depths of less than 50 m below the ground surface. The patterns of the local systems are multidirectional and broadly replicating the local topographic slopes.

The Huai Yai Hydrogeologic Province has its own unique property of a ratio of recharge to discharge area of approximately 1 to 2. The results of hydrogeologic and geomorphic mapping indicate that average water fluctuations in piezometers in recharge and discharge areas is about 0.15 to 2.5 m, varying from different topographic elevations as shown in Figure 4.6. Quantification of the recharge rates from the water-level fluctuations has been discussed in Chapters 2 and 7 (Table 7.2): the results of estimation of recharge rates in the flow systems, range from 8.56E-10 2.18E-08 m/s (2.3 to 58 % of the groundwater coefficient of precipitation, Kp) as shown in Figure 4.7.

4.4 Surface evidence

Surface evidence which was considered to be related to groundwater flow in the Khon Kaen Drainage Basin can be categorized into 2 main groups namely: 1) geomorphic features and 2) other related surface manifestations.

4.4.1 Geomorphic features

Figure 4.6 illustrates the genetic relationship between distributions of natural recharge and discharge areas and distributions of other mapping units of geomorphic features. The maps of soil-drainage classes and soil salinity indices were compiled from the Soil Survey Division (1973a, 1973b and 1989). Topographic elevations, soil-drainage classes, soil salinity indices and land types were classified and constructed as discussed in section 2.2.2.2 and are shown in Figures 4.8 to 4.11. These geomorphic features are evaluated with respect to the groundwater regime in terms of recharge and discharge areas and their relationship among themselves and the average water-level fluctuation in the aquifers.

Figures 4.4, 4.7 and 4.8 to 4.11 indicate that the recharge areas comprise the following geomorphic features: the well drained soil class (WDS), salinity indices nos. 5

and 6 (areas located in relatively high topographic elevations (>180 m amsl) and no indication of salt crust), land types of high ridge (Rv), broad ridge with gentle slope (R) and undulating to high level plains (Gu).

The relationship between groundwater flow regime and distributions of other related surface manifestations are quantified in Figure 4.6. The total land area in the Huai Yai Hydrogeologic Province classified as recharge area that comprises 85% of the surface uplands with a topographic elevation exceeding 180 m amsl (Figure 4.8). The total recharge area incorporates about 90% of the area with soils with salinity indices nos. 4 and 5 (Figure 4.10). The total recharge area also incorporates 78% of the well drained soil (WDS). The soil types exist this well drained soil classes (WDS) are: *Oxic Paleustults; Ustoxic Dystropepts; plinthustuits; Ustoxic Quartzipsanments; Typic Haplustox and Typic Pellusteris*. About 94% of the area of high and broad ridges of moderate slope (Rv), high and broad ridges of gentle slope (R) and gently undulating to high level plains (Gu) are found in the recharge areas (Figure 4.11).

The discharge areas on the other hand are commonly located in the lower topographic elevations (<180 m amsl) and covered with poorly to very poorly drained soils (PDS and VPDS) and commonly associated with salinity indices nos 1, 2, 3 and 4 (see Figure 4.10 for the explanation of the indices). More than 66 % of area with soil salinity index nos 1 to 4 are situated in discharge areas. About 65% of the total area of poorly drained soil (PDS) which consisting of the following soil types: *Typic Ustifluvents; Aeric Tropaquepts; Vertic Tropaquepts and Aeric Paleaquults* occur within areas of groundwater discharge. Moreover 90% of the flood plain areas with gentle to nearly level slopes (including some local salt affected areas (Fp) and alluvium plains (A) of the Huai Yai Creek and relict meander belts (Rm) associated with the Chi River, Figure 4.11) are commonly situated in discharge areas.

4.4.2 Other surface manifestations

Saline soils are commonly found in areas of shallow water table, poor drainage and saline artesian wells. The presence of saline soil usually indicates ascending groundwater. Flowing wells suggest that stream valleys are locations of zones of converging (and possibly upwardly discharging) flow. Salt mineral accumulations and salt tolerant plant communities can be recognized in the major discharge and highly salinised areas, i.e., west Ban Kok and Ban Sa-Art. The salt tolerant plants (halophytes, Plates 4.3 to 4.8) which were identified by Homchuen (1990, Personal Comm.) are commonly found only in the major discharge areas (0.2-0.5 km^2) such as the lower area at Ban Nong Lup, Ban Tum, Ban Sri Than, and west of Ban Sa-Art and the northern boundary at Bung Kaeng Nam Ton reservoir. The salt tolerant plants identified in discharge areas in the Huai Yai Hydrogeologic Province are (Thai name in brackets):

1. *Azima sarmentosa* (Nam Phong Do, Plate 4.3)
2. *Gisekia pharmacoides* (Pak Bia Daeng, Plate 4.4)
3. *Maytenus mekongensis* (Nam Daeng, Plate 4.5)
4. *Pluchea indica* (Khlue, Plate 4.6)
5. *Synostemon bacciformis* (Soy Nok Kao or Ma Fai Doen Ha, Plate 4.7)
6. *Massia triseta* (Yar Hua Kai, Plate 4.8).

In the Huai Yai Hydrogeologic Province, termite mounds are prominent features that can be observed in the areas where the water table is less than 1 m below the ground surface. Termites normally build the mound in order to distance themselves from water. The termite mounds may be one of the most visible indicators of the discharge area. Salt mounds which are evidence of human activity, can be locally observed in the highly salinised areas in the central region of the province (Figure 4.1, Plates 4.1 and 4.2).

4.5 Hydrochemistry

In order to qualitatively substantiate the validity of flow patterns and flow systems in the Huai Yai Hydrogeologic Province, samples of rain water, dug-well water, surface water and groundwater were analyzed and averaged in Tables 4.1 and 4.2. Six samples of rain water, RW8; RW9; RW10; RW16; RW18 and RW19, exhibit relatively lower TDS contents than the groundwater and surface water, ranging between 16 and 38 mg/l, and pH values of 6.30 to 8.20. According to Piper's diagram (Galloway and Kaiser, 1980), all rain water samples are Ca-HCO_3 facies. Surface water samples, SW16; SW17; SW22; SW26; SW29; SW30; SW35; SW36 and SW37, were taken from various types of water bodies, namely, rivers, swamps and ponds. Their mineralizations are variable with TDS contents ranging between 30 and 7800 mg/l, and pH values ranging from 6.9 to 7.48 (Table 4.2). Shallow dug-well water also contains relatively low TDS (29 to 266 mg/l), but wide range of ionic constituents, namely: Ca-HCO_3, Ca-Na-HCO_3 and Ca-Na-HCO_3-Cl facies (Table 4.1c).

4.5.1 Distribution of ionic concentrations and hydrochemical facies of groundwater

The areal distribution of TDS contents and of selected major ion ratios in the Huai Yai Hydrogeologic Province are depicted in the form of contour maps (Figures 4.12a to 4.12d). Figure 4.12a illustrates the areal distribution of TDS contents of water wells and springs. The map shows that groundwater in the Huai Yai Hydrogeologic Province is highly mineralized. About 60% of the province contains groundwater with TDS contents greater than 2000 mg/l, whereas only 25 to 30% of the province yields water with TDS contents less than or equal to 1000 mg/l. Mineralization occurs the least in the northern and western regions of the province, and increases towards the lower elevations in the southeast and eastern regions. Highly saline groundwater (6000 and 70000 mg/l of TDS) occurs in some locations such as Ban Nong Takai (P70), Ban Phradu (F624 and P34) and Ban Don Bom (WW19).

The ratio of magnesium with respect to calcium ion, (Mg^{2+}:Ca^{2+}) increases from 0.2 to 0.5 along the groundwater paths from recharge to discharge areas (Figure 4.12b). The ratios of Ca^{2+}:Na^{+} and SO_4^{2-}:Cl^{-} on the other hand decrease in the direction of flow from 3.0 to 0.1 and 0.5 to 0.01 respectively (Figures 4.12c and 4.12d).

Hydrochemical analyses of 54 groundwater samples were classified by plotting concentrations of major ions on the Piper trilinear diagram (Galloway and Kaiser, 1980) as depicted in Figure 4.13. Changes in overall groundwater chemistry in relation to flow patterns are revealed in the hydrochemical facies in both plan view and cross-sections as presented in Figures 4.13 and 4.14. Facies numbers are designed according to the Piper diagram in Figure 4.13. Consequently, seven hydrochemical facies of groundwater can be identified as follows:

Facies 1 Calcium-bicarbonate (Ca-HCO_3)
Facies 2 Calcium-sodium-bicarbonate (Ca-Na-HCO_3)
Facies 4 Calcium-chloride (Ca-Cl)
Facies 6 Sodium-bicarbonate (Na-HCO_3)
Facies 8 Calcium-sodium-bicarbonate-chloride (Ca-Na-HCO_3-Cl)
Facies 9 Sodium-sulfate-chloride (Na-SO_4-Cl) and
Facies 10 Sodium-chloride (Na-Cl).

Facies 1 (Ca-HCO_3 water) occupies about 10 % of the total areal extent area of the Huai Yai Hydrogeologic Province. This facies exhibits an average TDS content of 448 mg/l and an average pH of 7.00. Calcium plus magnesium forms an average 72 % of the total cations and HCO_3^- comprises 77% of the total anions. Ca-HCO_3 water is typically found in the wells located in recharge areas in the vicinity of the Phu Meng and Nong Lup ridges.

Facies 2 (Ca-Na-HCO_3 water), the average TDS content is about 688 mg/l, with an average pH of 7.31. Calcium and magnesium ions are the major cations of this facies (87 % of total cations), and HCO_3^- comprises at least 70% of the total anions. These waters dominate small areas in the north and south at Ban Muang and Ban Taen, comprising only 2 to 3 % of the total area of the province.

Facies 4 (Ca-Cl water) exhibits an average TDS content of 3300 mg/l, pH value of 6.94, Ca^{2+} and Mg^{2+} contents form 56 and 26 % of total cations respectively, Cl^- and HCO_3^-contents form 66 and 23 % of total anions. Ca-Cl water occurs in the southwest of the province at Ban Kaen Thao and in an isolated zone southeast of Amphoe Ban Fang.

Facies 6 (Na-HCO_3 water) is characterized by an average TDS content of 432 mg/l, and an average pH of 7.3. Ca^{2+}+Mg^{2+}, and Na^+ ions constitute 18 and 80 % of total cations respectively, and HCO_3^- comprises 94 % of total anions. This water occurs in a single isolated area at Ban Sa-Art that is saturated in waters of the Kaeng Nam Ton intermediate flow system (AI3-2).

Facies 7 (Ca-HCO_3-Cl water) exhibits TDS values that range from 160 to 1300 mg/l, and an average pH of 7.22. Average Ca^{2+}+Mg^{2+} forms 75 % of total cations, while HCO_3^- and Cl^- comprise 36 and 55 % of total anions respectively. This type of water is found at the relatively low elevations <180 m above amsl) between the Ca-HCO_3 and Na-Cl facies at Ban Sawathi and east of Ban Nong Wang Hi.

Facies 8 (Ca-Na-HCO_3-Cl water) exhibits an average TDS content of 431 mg/l and pH value of 6.74. Ca^{2+}+Mg^{2+}, and Na^+ constitute 51 and 46 % of total cations respectively, and HCO_3^- and Cl^- comprise 75 and 24 % of total anions respectively. This facies dominates about 8 % of the total area of the province along the western strip of the mid slope where there is contact between the sand and gravel unit (Qsg), and the Mahasarakham unit (Kms).

Facies 9 (Na-SO_4-Cl water) is local in extent and is found, at Ban Sri Than (south of Khon Kaen university campus). The average TDS content ranges 2100 - 43000 mg/l.

About 70 % of total anions is Na^+ and 80 % of total cations is Cl^- and SO_4^{2-}. The high SO_4^{2-} may be due to the dissolution of gypsum from the top layer of the Kkk by percolating groundwater and transported upward by Ban Sri Than intermediate flow system (AI3-1).

Facies 10 (Na-Cl water) is the most abundant water type and extends over about 60 % of the whole area of the province. The TDS content is relatively high, ranging from 1600 to 75000 mg/l and total cations are more than 70 % Na^+. Na-Cl facies occurs in the central region which is the discharge area and along the alluvial plains of the Huai Yai Creek and Chi River.

The sequence of hydrochemical facies developed along particular flow paths in the Huai Yai Hydrogeologic Province can be categorized into a series of individual groundwater flow systems as summarized in Table 4.6.

4.5.2 Stable isotopes

At 20° C, water vapor is lower by about 80% in deuterium (D) and 10% in oxygen-18 ($\delta^{18}O$) than water in the liquid stage but is in isotopic equilibrium. Kinetic isotopic effects during evaporation lead to greater fractionation. Water vapor that has evaporated from oceans is depleted in deuterium and oxygen-18; however it is not quite in isotopic equilibrium with the oceans. This is due to the effects of wind, imperfect mixing and kinetic factors affecting the mass transfer between the liquid and vapor phases. The major effects of continuous removal of condensate enriched in the heavier isotopes (Wallick et al., 1984) are: a gradual decrease in δD and $\delta^{18}O$ as one goes from lower to higher latitudes (or decrease in δD and $\delta^{18}O$ with increasing altitude); more depletion in δD and $\delta^{18}O$ in winter snow than in summer rains, and a decrease in δD and $\delta^{18}O$ in going from the coast to inland.

The unconfined aquifers are generally more enriched in heavy isotopes with a large range in stable isotopic compositions than confined aquifers (Love, et al., 1993). The isotopic compositions for the unconfined aquifers have less correlation to the flow path. This is due to the effect of local flow systems in the unconfined aquifers.

The departure of δD and $\delta^{18}O$ concentrations from the meteoric water line is a feature of the isotope analysis that can be used in a variety of hydrologic investigations (Freeze and Cherry, 1979 and Wallick et al., 1984). The various processes that cause a departure from the meteoric water line are evaporation from an open water body, condensation, exchange with gases and solids, and hydration of sulfate and silicate minerals (Mazor et al., 1985). Certain ions are conservative, once they have entered the groundwater they remain in it as there is no mechanism such as chloride and bromide to remove them. Their concentrations are either constant or increase down flow with the dissolution of salts. Other ions, e.g., calcium, magnesium, sodium and potassium may be reactive, which are participating in water-rock interactions, often enhanced by temperature changes.

A plot of δD versus TDS contents of rain water and groundwater in the Huai Yai Hydrogeologic Province in Figure 4.16a indicates that the composition of δD in recharge groundwater range from -60 to -30‰ which are similar to the rain water values of -48 to -39‰. Figure 4.16a indicates that δD content (-55‰) in the wells along the flow path in the Ban Khok Kwang intermediate flow system (AI1-1) is relatively low compared to δD content (-37‰) in the wells along the flow path of Ban Sri Than intermediate flow system (AI3-1). The δD concentration is less in the flow path of the flow system AI1-1 because the recharge area of this flow path is located in higher topographic elevation than the recharge area of the AI3-1 flow system. There is some horizontal displacement of TDS contents from recharge areas to discharge areas between wells, WW1 to WW2 and P73 without changing δD values (Figure 4.16a). This may be due to dissolution of evaporites or rock salts of the Mahasarakham unit (Kms). The average amount of $\delta^{18}O$ concentrations in groundwater (-3.82 to -6.88‰) in Figure 4.16b is close to $\delta^{18}O$ concentrations of rain water (-4.5 to -8‰). There is some scatter of data points of δD and

$\delta^{18}O$ in recharge and discharge areas which are difficult to differentiate. This may be due to the effects of local flow systems in the shallow wells.

4.5.3 Hydrochemical processes

The selected flow paths of the Phu Meng (AR1) and Nong Lup (AR3) regional systems (Figures 4.14 and 4.17b) were chosen to examine their possible hydrochemical evolution.

4.5.3.1 Hydrochemical evolution along flow path AR1-AR1' for Phu Meng regional groundwater flow system (AR1)

Rain water (RW13), collected within the confines of the Phu Meng regional flow system (AR1), exhibits TDS contents of 21 mg/l. The rain water is of the Ca-HCO_3 facies with a pH of 6.5. The piezometers installed along the flow paths AR1-AR1' are P01, P639, P459 and F761. Groundwater recharges to well P01 and flows over a distance of about 20 km to the discharge area at well F761 (Figures 4.14 and 4.17a). Recharge groundwater in siltstones and sandstones of the Khok Kruat unit (Kkk) in the western region (Ban Don Du and Ban Nong Bua) have low TDS contents as well. Mineralization increases downstream with TDS contents ranging from of 257 to 611 mg/l in the recharge area to 3820 mg/l in the discharge area. These waters vary in compositions but HCO_3^- is the dominant anion, and Ca^{2+} is the dominant cation. These recharge waters are neutral with pH ranging from 6.92 to 6.95. The dominant ions along the entire flow trajectory AR1-AR1' are: $Ca^{2+}>Na^+>Mg^{2+}>K^+$and $HCO_3^->Cl^->SO_4^{2-}$ in the recharge areas and $Na^+>Ca^{2+}>Mg^{2+}>K^+$ and $Cl^->SO_4^{2-}>HCO_3^-$ in discharge areas (Figure 4.18a and Table 4.7a). The potassium concentration increases along the flow path; whereas the silica concentration in the recharge waters is relatively high (45 mg/l) compared to the discharge waters (34 mg/l).

Figure 4.19 shows the concentrations of individual ions in relation to the Cl^- ion , which is essentially conserved in solution during the evolutionary processes considered here. Arrows on the plots indicate the downstream order of the samples along the two flow paths. Positive correlation lines oriented at 45° indicate no change in relative proportions of ions. The downstream decrease in Na^+ in relation to Cl^- concentration is balanced by an increase in both Ca^{2+} and Mg^{2+}, suggesting that reverse cation exchange may be operating along the flow path, removing Na^+ ions from solution and replacing them with Ca^{2+} and Mg^{2+}. SO_4^{2-} as shown in Figure 4.19 decreases absolutely with increasing Cl^-, while HCO_3^- increases slightly. SO_4^{2-} may be reduced and removed from solution by the bacterially mediated oxidation of organic materials (sulfate reduction) which simultaneously adds HCO_3^- to the water. However, there is no evidence of low pH in this water. The groundwater in the discharge area remains undersaturated with respect to gypsum and anhydrite (Figure 4.21 and Table 4.8). The hydrochemical facies of the discharge waters are Ca-Cl to Ca-Na-Cl. The Cl^- and Ca^{2+} are dominant in well water (F459 and F716) and when plotted in the expanded Durov diagram (Figure 4.22) support the postulation that the high Ca^{2+} and Cl^-concentrations in the discharge waters along the flow path AR1-AR1' result from reverse cation exchange (Lloyd and Heathcote, 1985).

Figure 4.20 shows the relationship of other ionic parameters along the flow path AR1-AR1'. $SO_4^{2-}$and Ca^{2+} ions initially increase, probably due to calcite dissolution in recharge areas. Then Ca^{2+} still increases while the SO_4^{2-}decreases in discharge areas as a result of reverse cation exchange and probably sulfate reduction. A similar pattern is evident in the diagram in Figure 4.20 showing the relationship of Ca^{2+} versus Mg^{2+} and Ca^{2+} versus $HCO_3^-+SO_4^{2-}$.

The major hydrochemical processes related to other hydrogeological parameters along the flow path AR1-AR1' (20 km long) in the Phu Meng regional flow systems are: dissolution of calcite, dolomite and silicate minerals in recharge areas and dissolution of evaporites minerals (carnallite, sylvite, halite, anhydrite and gypsum), reverse ion exchange and sulfate reduction in the relatively saline discharge waters. These processes are summarized in Figure 4.17a. The calculated ionic strength of groundwater increase from 0.0060 to 0.0875 from recharge to discharge areas respectively (Table 4.8).

4.5.3.2 Hydrochemical evolution along flow path AR3-AR3' for Nong Lup regional flow system (AR3)

Rain water (RW12), collected at the Khon Kaen University campus, exhibits 68 mg/l TDS content. The water is Ca-HCO_3 facies with a pH of 7.60. The piezometers situated along the flow path AR3-AR3' are P12, PWKS, P17 and P18. Groundwater recharges in the University campus at wells P12 and PWKS, flows downward, then laterally to the south before discharging upwards at Ban Kok where wells P17 and P18 are located. The total flow path AR3-AR3' is approximately 12 km in length as shown in Figures 4.14 and 4.17b. The TDS contents of groundwater in the sand and gravel unit (Qsg) is about 200 mg/l and increases along the flow path to a level of 6000 mg/l in the shales and siltstones of the Mahasarakham unit (Kms). The hydrochemical facies that occur along the flow path AR3-AR3' are Ca-HCO_3 to Na-Cl. Ca^{2+}, SiO_2 and HCO_3^- (Figure 4.18b) show an initial increase in the recharge area and then decrease along the flow path. This may be due to the dissolution of calcite cement in siltstones, and silicate minerals by the recharge waters. Both Cl^- and Na^+ increase consistently with increased TDS contents. The cation and anion dominance sequences (Figure 4.18b) are more or less similar in pattern to the flow path AR1-AR1' except at the discharge area at P17 and P18 where the TDS contents are decreasing at P18. The TDS contents of groundwater decreased from 6000 mg/l in P17 to 2100 mg/l in P18 as well as other ionic contents. This may be because the groundwater in P18 was diluted by local and intermediate flow systems that are superimposed on the regional system. It is clear from the result that the dilution process has occurred. But the mechanism of the dilution is unknown.

The correlation line for Na^+ versus Cl^- (Figure 4.19) shows that both ions increase in concentration downstream with some relative depletion of Na^+. The main source of these ions is halite derived from the evaporite minerals of the Mahasarakham unit (Kms). A single source for Ca^{2+} and Mg^{2+} ions may be due to cation exchange and is supported by the plot on Figure 4.20, which shows similar patterns for both Ca^{2+} and Mg^{2+} versus

HCO_3^-. Both Ca^{2+} and Mg^{2+} increase in concentration downstream (from wells PWKS to P17) as HCO_3^- decreases.

For much of the southern portion of the flow path or in the discharge area (P17 and P18), the correlation line of SO_4^{2-} versus Cl^- (Figure 4.19) deviates from 45° and the ratio of SO_4^{2-}/Cl^- is much less than 1.0. An increase in SO_4^{2-} with increasing Cl^- in the recharge area probably indicates dissolution of sulfate minerals such as gypsum and anhydrite. The relative by minor increase in K^+ relative to Cl^- as indicated by the correlation line in the K^+ versus Cl^- plot (Figure 4.19) suggests that sylvite (KCl) dissolution is unimportant.

Saturation indices calculated in Table 4.8 and Figure 4.21 indicate that all groundwater samples are undersaturated with respect to calcite dolomite, gypsum, anhydrite and halite. The TDS contents in these groundwater samples do not exceed 43000 mg/l at the average temperature 30° C. The calculated ionic strengths of groundwater samples increase from 0.0044 to 0.1708 relative to the groundwater samples taken from the flow path AR1-AR1' from recharge to discharge areas respectively. The low ionic strength (0.0386) of the groundwater sample from P18 may be due to mixing and dilution.

The major hydrochemical processes along flow path AR3-AR3' are: dissolution in both recharge and discharge areas, simple dissolution and cation exchange in the midline area, and mixing with relatively dilute shallow groundwater or local and intermediate flow systems (Ban Sa-Art system, AL3-1 in Figures 4.3 and 4.4) at well P18 (Ban Kok).

4.6 Flow patterns and systems determined by field evidence

Groundwater flow patterns in the Huai Yai Hydrogeologic Province as constructed are based on piezometric analysis and confirmed by surface evidence of related geomorphic features such as topographic expression, soil-drainage class, salinity index and land type. However the soil salinity index alone may not be a good indicator to differentiate between recharge and discharge patterns, because the main soil salinity indices (nos.4 and 5) in the province are situated in both recharge and discharge areas. However, the distribution of salt crusts on the surface and the community of salt tolerant plants typically characterize the areas of ascending groundwater.

The regional groundwater flow pattern in the Huai Yai Hydrogeologic Province is mainly controlled by topographic terrain and geologic structures i.e., faults, anticlines, and synclines. The contrast in permeability of aquifers and aquitard has less effect upon the flow distribution. The results of numerical simulations may offer further evidence on this point. Several local and intermediate flow systems are superimposed on the regional systems which commonly exist in the undulating topography. Groundwater generally flows down dip and down the plunge of the anticlinal structure within the aquifers (in the vicinity of Khon Kaen university campus). The regional groundwater flow systems of the province are controlled by topography and regional faults which act as water divides which control the groundwater flow pattern. The flow patterns can then be further divided into provinces of unconfined flow condition. The groundwater regime in the Huai Yai Hydrogeologic Province may be characterized as a type of "***a broad anticline-synclinal province***"

4.7 Mathematical Model

4.7.1 Model design and input parameters

The theoretical investigation of flow in the Huai Yai Hydrogeologic Province was carried out with the aid of a three dimensional mathematical model. The model consists of 44 nodes in the x (east-west) horizontal direction, and 40 nodes in y (north-south) horizontal direction which discretize the province in plan view. The horizontal node spacing is 1000 m. The vertical discretization was achieved with 26 nodes spaced at 20 m intervals. The bottom layer represents rock salt unit (rs, 100 m thick) as shown in Figures 4.23 and 4.24. The ratio of horizontal to vertical nodal spacing is 50:1.

Setting boundary conditions is the step in model design that is most subject to serious error (Anderson and Woessner, 1992). Under steady-state conditions, the boundaries largely determine the flow pattern. In two-dimensional and in full three-dimensional models, specified head nodes may be assigned heads equal to the water-table elevations of surface water bodies. Such water table elevations were estimated from the topographic elevations existing in the Huai Yai Hydrogeologic Province by adjusting the values from the correlation of topographic elevations and measured hydraulic heads in Figure 4.5. The hydraulic heads in the recharge and discharge areas are subtracting 15 to 10 m and 1.5 m respectively from the topographic elevations at particular grid blocks. Alternatively, the water table can be represented as a specified flux boundary by quantifying the varying magnitudes of recharge and discharge over its surface.

Initial values of hydraulic conductivity assigned to the various hydrogeologic units were determined from the results of pumping tests and other related works as shown in Table 3.1. The horizontal and vertical hydraulic conductivities for aquifers which were used as input parameters in the model are shown in Figure 4.24. In a block-centered finite difference grid, no-flow boundaries were simulated by assigning zero transmissivities or hydraulic conductivities to the inactive cells just outside the boundary. No-flow boundaries in this study area exist at the groundwater divides in the north (Nong Lup Ridge) and west (Phu Meng Ridge) and also along the impermeable fault zones under the Phong-Chi and Chi rivers in the east and southeast, and the fault line along Na Klang Creek in the south. The bottom layer (layer no. 26) of the model is also a no-flow boundary, represented by rock salt unit (rs) of the upper Mahasarakham unit (Kms). The upper surface of this layer is situated at an elevation of -280 m amsl.

4.7.2 Model calibration and sensitivity analysis

The model was calibrated against groundwater heads derived from the measured hydraulic heads. The calibration procedure is based on the comparison between the field and the model results of the best fit in hydraulic head and the patterns of recharge-discharge areas.

Results of several simulations and sensitivity analysis are presented in Table 4.9 and Figure 4.25. Systematic changes of input parameters to the model, i.e., values of horizontal and vertical hydraulic conductivity of aquifers and aquitards in terms of homogenous and/or isotropic, heterogeneous and anisotropic throughout the flow domain, and changing position of boundaries. Calibration of the simulated hydraulic head against the measured hydraulic head in the Huai Yai Hydrogeologic Province was performed by trial and error until the simulated head was in reasonable agreement with the field measurements throughout the province. The final simulation (simulation no. refA-D.xyz Figure 4.25j) shows the difference between measured and calculated head ranging between +11.00 and -5.00 m with a root mean squared error (RMS) of 3.45 m. However, the sensitivity analysis was performed to examine the effects of varying hydraulic conductivities, degrees of anisotropy (Kx:Ky and Kx or Ky to Kz), and alternative positions of the basal boundary of the model.

4.7.3 Flow systems determined by numerical simulations

The results of the mathematical model for the Huai Yai Hydrogeologic Province are presented as plan view maps and also vertical cross-sections of the hydraulic head, flux and areal variations in recharge and discharge rates as shown in Figures 4.26a, 4.26b, 4.27a and 4.27b respectively.

Figures 4.26a and 4.26b demonstrate the final simulation of hydraulic head and flux in plan view for the model layers 6 and 10. The simulated pattern of equipotential lines is generally comparable to the field pattern as shown in Figure 4.4. The slight differences can be seen in the vicinity of higher elevations in the western region (Phu Meng Ridge). The simulated potentiometric surface exhibits more uniform hydraulic gradient and higher values than the field data. This may be due to the water table in the high topographic elevation being less subdued to the topographic configuration than the lower area. The highest values of horizontal flux clearly occur in the midline areas between recharge and discharge areas throughout the Huai Yai Hydrogeologic Province particularly along the model layer no. 15 (Figure 4.26b).

Figures 4.27a and 4.27b show the distributions of the simulated potentiometric surface, fluxes and recharge and discharge rates across the hydrogeologic profiles H1-H1' and H2-H2' respectively. The estimations of the provincial parameters by piezometric analysis and by the modeling technique for particular regional flow systems in the Huai Yai Hydrogeologic Province are tabulated in Table 4.10.

The hydrogeologic province parameters calculated by the piezometric analysis and by the model simulations are comparable, particularly recharge-discharge patterns, the distribution of equipotential lines and rates of recharge and discharge (groundwater coefficient of precipitation, Kp). Flux and natural basin yield values determined by the model technique are, on the other hand, lower than those obtained by piezometric analysis by about one and two orders of magnitude (Table 4.10). The differences between these parameters calculated by the two methods are due to the fact that the piezometric analysis method is based on water level fluctuations in the monitoring piezometers and assigned medium porosity at the specific sites. The specific yield of the porous media may be over estimated which would provide relatively high fluxes and natural basin yields. Another reason for higher estimations by the piezometric analysis, may be due to the incompletely sealed flow systems which did not satisfy the assumption as mentioned in 2.3.3 (Chapter 2). The recharge and discharge rates may also include the additional effects of some abnormal rainfall events during the dry season. Nevertheless, the results of fluxes and natural basin yield calculated by the 3-D models probably represent the minimum and reasonable values in order to utilize the model for groundwater development in the Huai Yai Hydrogeologic Province.

Figures 4.27a and 4.27b present the recharge and the discharge profiles along the hydrogeologic sections H1-H1' and H2-H2' and indicate the recharge rates in the sand and gravel unit (Qsg) to be about 2 to 3 times higher than in the conglomeratic sandstone of the Phu Phan (Kpp) and shales in the Mahasarakham (Kms) units.

Figure 4.28 shows that the model identified three distinct zones of regional recharge: the west (Phu Meng Ridge), southeast (Ban Nong Wang Hi) and the north (Nong Lup Ridge). These three areas coincide with the recharge areas of the main regional groundwater flow systems identified by piezometric analysis and field mapping (Figure 4.4). The simulated patterns of recharge areas agree well with the observed patterns. Some patterns of local flow systems cannot be detected by the model such as at Ban Muang and Ban Sa-Art in the center of the province. This is due to the coarse horizontal grid spacing (1000 m) of the model grid. The choice of cell spacing is constrained by data availability. If one wished to equate recharge with basin yield, a cell spacing that captures the general water-table curvature is appropriate. The simulated recharge rates vary from greater than 1.16E-10 to 6.94E-09 m/s. The highest recharge rates occur in the sand and gravel deposits (Qsg) located in the north at Nong Lup Ridge. The areal distribution of simulated recharge and discharge rates can be classified into four categories namely: >0.0-2.00E-09 , 2.00E-09 - 5.00E-09 , 5.00E-09 - 10.00E-09 and >10.00E-09 m/s, as shown in Figure 4.28. Recharge and discharge rates between 0.0 and 1.16E-09 m/s which falls in the ranges of the piezometer analysis. The total recharge areas are about 25 and 32 % of the total of the Huai Yai Hydrogeologic Province which are determined by the field mapping and the modeling respectively.

Chapter 5: Groundwater flow in Chonnabot Hydrogeologic Province:

An anticlinal-faulted block province

5.1 Location and topography

Chonnabot Hydrogeologic Province is situated between latitudes 16°05' and 16°16' N, and longitudes 102°32' and 102°42' E, covering an area of approximately 176 km^2. The region is about 11 km from east to west and 18 km from north to south (Figure 5.1). The topography is of relatively high relief with a complex sinusoidal surface of elongated and undulating hills in the central region. The major surface water divide trends north to south with elevations ranging from 180 to 240 m amsl. The average slope of the topographic surface is about 0.001 to 0.007. The Chonnabot Hydrogeologic Province is areally bounded by perennial streams to the north (Na Klang Creek) and west (Sai Kai Creek), and by the Chi River in to east and south.

5.2 Geology and hydrogeologic units

The Chonnabot Hydrogeologic Province occupies a NNW trending symmetrical anticline, with beds dipping about 5° on its flanks. The lower Triassic and Jurassic rocks of Huai Hin Lat (Thl), Nam Phong (Tnp), Phu Kraduang (Jpk), Phra Wihan (Jpw) and Sao Kua (Jsk) Formations were defined as the Jpk hydrogeologic unit (Figure 3.2) that is unconformably overlain by fine to medium grained sandstones and siltstones of the Khok Kruat unit (Kkk). The Kkk unit is conformably overlain by shales of the Mahasarakham unit (Kms), that is also exposed at the crest of the anticline in the central region. The remainder of this province is covered by a thin sand and gravel unit (Qsg, Figure 5.1).

The prominent aquifers are similar to the Huai Yai Hydrogeologic Province except for the sand and gravel unit (Qsg) that forms a relatively thin 1 to 2 m thick layer of sand and gravel unit (Qsg) which covers about 70% of a arable land. The Qsg unit is mainly deposited within a thin veneer and unsaturated with groundwater. It is considered to be an aquitard.

Existing hydrogeologic information in the Chonnabot Hydrogeologic Province is somewhat limited because there are only 9 piezometers installed (Table 5.3). Most of the piezometers were screened in the Mahasarakham unit and only one well monitored in the Khok Kruat unit.

5.3 Piezometric analysis of regional groundwater flow

The distribution of fluid potential was evaluated across the hydrogeologic profile H3-H3" (Figure 5.2) based on measurement of the average non-pumping water levels in piezometers WW13, P45, P48, P50, P77, and L791. The distribution of hydraulic potential is strongly controlled by various types of topographic terrain. The recharge areas are located in the water divide in the elongated hill of Suan Pa Muncha and the higher undulating terrain at Ban Nong Pen. The regional groundwater flows along the dip of the beds which is to the Chi River in the east and towards Sai Kai Creek in the west. The inferred equipotential lines and the flow directions over the entire province were deduced by the combined interpretations of piezometric analysis, geomorphic features and hydrochemistry.

5.4 Surface evidence

5.4.1 Geomorphic features

Geomorphic features including the mappable units of topography, soil-drainage class, salinity index, land type and other related surface manifestations are directly related to the groundwater flow regime in the Huai Yai Hydrogeologic Province as discussed in Chapter 4. Figure 5.2 demonstrates the relationship between recharge and discharge areas across the hydrogeologic profile H3-H3". The recharge areas are situated in relatively high topographic elevations (>190 m amsl) in the elongated hill and undulating terrains which is covered with well drained soil (WDS) and salinity index nos. 5 and 6. As well the land type of high and broad ridge of moderate slope (Rv) and a broad ridge of gentle slope (R) can be applied to this study area.

Figures 5.3 to 5.6 are the surface maps of the topographic elevation ranges, soil-drainage class, soil salinity index and land type existing in the Chonnabot Hydrogeologic Province. The inferred recharge and discharge areas over the entire province were mapped based on the integration of the piezometric analysis with the geomorphic and hydrochemical mapping techniques. The individual maps of geomorphic features are superimposed on each other. Subsequently, the boundary of each individual geomorphic feature can be drawn. From this technique, two distinct areas are delineated as recharge and discharge areas and the boundaries between them can be mapped as shown in Figure 5.1. The areas consist of about 120 and 56 km^2 respectively.

The recharge area which comprises 78% of the Chonnabot Hydrogeologic Province uplands (>180 m amsl, Figure 5.3), about 78% of the well drained soil (WDS, Figure 5.4), and 60% of soils with salinity index nos. 4 and 5 (Figure 5.5). Eighty six percents of the total area of the Chonnabot Hydrogeologic Province is composed of three land types: high and broad ridges of moderate (Rv); to gentle slope high and gentle slope (R) and gentle undulating to high level plains (Gu) as shown in Figure 5.6)

On the other hand, the discharge area is composed of about 93% of the lowlands (<180 m amsl), about 67% of the area is flood plain, with gentle to nearly level slopes, with some local salt affects (Fp), and relict meander belts of the Chi River, (Figure 5.6), 48 % of the total area of poorly drained soils (PDS) and 22% of the total area of very poorly drained soils (VPDS). The soil type identified in the discharge areas are: *Typic Ustifluvents; Aeric Tropaquepts; Vertic Tropaquepts* and *Aeric Paleaquults* (Figure 5.4).

5.4.2 Other surface manifestations of groundwater flow

Mineral salt accumulations and halophytic plant communities can be recognized in the southeastern region near Amphoe Chonnabot within the flood plain of the Chi River. Common salt tolerant plants in this area are: *Azima sarmentosa* (Nam Phong Do) and *Maytenus mekongensis* (Nam Daeng).

5.5 Hydrochemistry

About one-third of the province is underlain by water with TDS contents greater than 2000 mg/l (Figure 5.7a). Mineralization is least in the central and western regions. TDS contents greater than 2000 mg/l occur in the eastern region at Ban Non Ngiew (L791) and Ban Nong Paen (P50).

The ratio of $Mg^{2+}:Ca^{2+}$ increases from 0.4 to 1.4 along the groundwater flow paths from Huai Hin Keang towards the lower flood plain of the Chi River in the east (Figures 5.7b). The relative amount of Ca^{2+} with respect to Na^{+} decreases with decreasing elevation the high to low elevations from 1.4 to 0.2 (Figure 5.7c). Whereas, the distribution of $SO_4^{2-}:Cl^{-}$ (Figure 5.7d) increases with the decreasing elevation from 0.3 in the central region, 2.3 near periphery of the province.

Hydrochemical facies are classified and presented in plan view and in the cross section (Figures 5.8 and 6.7a). The four main hydrochemical facies identified in the Chonnabot Hydrogeologic Province are as follows:

Facies 1. Calcium bicarbonate ($Ca\text{-}HCO_3$)

Facies 2. Calcium-sodium-bicarbonate ($Ca\text{-}Na\text{-}HCO_3$)

Facies 9. Sodium-Chloride (Na-Cl)

Facies 10. Sodium-sulfate-Chloride ($Na\text{-}SO_4\text{-}Cl$)

Facies 1; $Ca\text{-}HCO_3$ water occurs in the higher regions (>200 m above amsl) in the center of the province. About 30 % of the total area (Figure 5.8) is occupied by the $Ca\text{-}HCO_3$ water with a TDS content of about 400 mg/l and a pH of 6.9. Ca^{2+} and Mg^{2+} together total 68 % of the cations, and HCO_3^- constitutes 90% of the total anions.

Facies 2; $Ca\text{-}Na\text{-}HCO_3$ water has an average TDS of about 500 mg/l and an average pH of 7.19. $Ca^{2+}$and Na^{+} are the major cations of this facies with 92% of total cations, and HCO_3^- constitutes at least 51% of the total anions. This water dominates in the mid slope regions of the province and occupy about 40 % of the total area.

Facies 9; Na-Cl water has an average TDS content of 2100 mg/l. Na^+ is the major cation and comprises more than 61% of the total cations.

Facies 10; Na-SO_4-Cl water has an average TDS content of about 5200 mg/l, and Na^+ comprises more than 50% of the total cations. Chloride plus sulfate comprise 90% of the total anions. Both Na-Cl-SO_4 and Na-Cl facies occur in the lowland areas (<160 m above amsl) in the east, south and west of the province and along the alluvial plains of the Chi River.

5.6 Flow patterns and systems determined by piezometric analysis and field evidence

The average depths of the water table in the Chonnabot Hydrogeologic Province is 4 to 18 m in the recharge area and less than 1 m in the discharge area. Cross formational flow is a regionally significant aspect of groundwater movement in this region. Lateral hydraulic head gradient, decreasing down dip in the aquifers suggests that groundwater flow rates are decreasing in down dip direction and that some upward cross formational flow occurs within the fault zones which are located along the course of the Chi River in the south and east of the province boundaries (Figures 5.2 and 5.9).

Groundwater flow systems were identified with regards to the geometry of the flow domain and hydraulic parameters (i.e. direction and magnitudes of flux and recharge and discharge characteristics of an individual area). The following groundwater flow systems were identified in Chapter 7 and illustrated in Figure 5.2 and 5.9, and Table 5.6).

Huai Hin Keang regional system (BR1)

Ban Nong Ben local system (BL1-1)

where: B represents Chonnabot Hydrogeologic Province, R, I and L are regional, Intermediate and Local flow systems respectively.

Huai Hin Keang is the only regional system identified in the Chonnabot Hydrogeologic Province. Precipitation recharges through the water divide located in the center of the province (Figures 5.2 and 5.9). Groundwater flows in shales and siltstones of the Khok Kruat unit (Kkk) downward, and laterally to the west and east and subsequently upward across the shales of Kms unit. The flow path ranges from 8 to 10 km in length and its depth is approximately 170 m. Its average maximum flux is 4.82E-07 m/s (Table 5.6). A local flow system, Ban Nong Ben (BL1-1, Figure 5.2 and 5.9).

5.7 Hydrochemical processes

The groundwater flow systems developed in Chonnabot Hydrogeologic Province comprise 4 hydrochemical facies. The sequence of each facies along the particular flow path in the Chonnabot Hydrogeologic Province is summarized in Table 5.7

5.7.1 Hydrochemical evolution along flow path BR1-BR1' for Huai Hin Keang regional groundwater flow system (BR1)

Rain water collected at Chonnabot meteorological station (RW7) has a TDS content of 79 mg/l (Table 5.1). The rain water is the Ca-HCO_3 facies water with a pH of 7.1. The groundwater recharges in the central region of the province at well WW3 flows downward and easterly through Ban Nong Paen (P50) and then upwards at the western bank of the Chi River at well P77. The total flow path BR1-BR1' is approximately 8 km long as shown in Figures 5.9 and 5.11. TDS contents of the recharge water range from 88 to 273 mg/l which is close to the TDS content of the rain water and increases down the flow path to a maximum value of about 43000 mg/l in discharge area. The dominant ions in the recharge waters along the flow path BR1-BR1' are $Ca^{2+}>Na^{+}>Mg^{2+}>K^{+}$and $HCO_3^{-}>Cl^{-}>SO_4^{2-}$ whereas the discharge waters are dominant in $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ and $Cl^{-}>SO_4^{2-}>HCO_3^{-}$ (Table 5.5 and Figure 5.12).

To gain some insight into the complexities of the hydrochemical evolution along the flow path BR1-BR1' the relationships of the concentrations of individual ions to the Cl ion and the relationships of various other ionic parameters were plotted and resulted in Figures 5.12 and 5.13 respectively. Both Ca^{2+} and HCO_3^{-} initially increase due to calcite and dolomite dissolution and then decrease as a result of the carbonate precipitation of calcite and dolomite. Calculated saturation indices show that these groundwaters are undersaturated with respect to anhydrite, gypsum and halite (Figure 5.14 and Table 5.8). The discharge groundwaters however are saturated with respect to calcite and dolomite in water, with a TDS content greater than about 2000 mg/l. The Na^+:Cl^- molar ratio (8.36) is high in the recharge area where the Cl^- content is relatively low (0.30 meq/l) in the siltstones of the Kkk unit. The Na^+:Cl^- ratio falls close to unity (3.86 to 0.76, Figures 5.10 and 5.12) within the discharge area, possibly due to the affects of the dissolution of halite from the Mahasarakham Formation. The halite dissolution would also be explained by plotting the ionic contents in the expanded Durov diagram (Figure 5.15) The linear development of the hydrochemical facies along the flow path indicates simple dissolution processes (Lloyd and Heathcote, 1985).

The ratio of Mg^{2+}:Ca^{2+} increases from 0.35 to 1.40 along the flow path (Figure 5.10), but Ca^{2+}:Na^+ decreases. The ionic strength of these groundwaters increases from 0.0085 to 0.8467 from the recharge to the discharge area. Both of these processes may be explained by a simple dissolution along the flow path.

The main hydrochemical processes along the flow path BR1-BR1' are: dissolution of calcite and silicate minerals in the recharge area, dissolution of evaporites, gypsum, anhydrite and sylvite, and the diffusion of halite from the Mahasarakham unit (Kms) as shown in Figure 5.12.

No mathematical model was prepared for the Chonnabot Hydrogeologic province. The detailed hydrostratigraphy and hydraulic parameters of aquifers cannot be determined because the limited information available. The significant controlling factors of groundwater flow regime in the Chonnabot Hydrogeologic Province are topographic expression and geologic structures found within the areas, i.e., anticline and faults. The pronounced elongated and undulating topography in the relatively high elevations are strongly influential in generating local flow system. The regional flow systems may be governed by the province boundaries that are a series of fault lines and zones on which the existing Chi River, Sai Kai and Na Klang creeks are developed.

Distribution of ionic concentrations are typically conformed with the flow pattern as a series of Chebotarev's sequence. Furthermore, the hydrochemical evolution along the known flow path is controlled by the aquifer compositions or lithology.

In order to construct the flow pattern and flow systems in the Chonnabot Hydrogeologic Province where the available piezometers are limited, the application of geomorphic mapping and characteristic of hydrochemistry of surface water and groundwater are substantially useful tools.

Chapter 6: Groundwater flow in Hin Tank Hydrogeologic Province

A faulted block province

6.1 Location and topography

Hin Tank Hydrogeologic Province is located between latitudes 16°00' and 16°25' N, and longitudes 102°40' and 103°15' E covering an area of approximately 1110 km^2. It extends approximately 40 km from north to south and 40 km from east to west (Figure 6.1). The Hin Tank Hydrogeologic Province is a good example of a fault block province with a high density of sub angular and trellis type drainage patterns. The surface topography is a sinusoidal, complex and undulating terrain.

The fault zones are occupied by the major streams found in the Hin Tank Hydrogeologic Province. The streams are major normal and strike slip faults. The fault zones are delineated by the 4 major streams: the Phong, Chi rivers, Huai Taen and Huai Kut Chuak Creeks which are located in west, north, east and south respectively.

6.2 Geology and Hydrogeologic units

Hin Tank Hydrogeologic Province is underlain by shales of the Mahasarakham Formation (Kms) and some rock salt (rs) units at an average depth of 200 to 250 m and by sandstones, siltstones and shales of the Phu Tok Formation (Tpt) in the central area of the province. The Phu Tok Formation are reddish brown to reddish orange, fine to medium grained and characteristically well sorted. They are cross-bedded and laminated to massively bedded and interbedded with siltstones and shales. The outcrop of the unit shows some lineations of fractures, like the areas found at Palan Hin Kaeng (Plates 6.1 and 6.2). The lineaments can also be traced from aerial photos. Highly fractured zones are commonly detected through mud loss while rotary drilling in the areas of WW3 and WW4. Pumping tests were carried out in wells, WW3, WW4, WW16 and PWLR providing wide ranges of horizontal and vertical hydraulic conductivities (2.22E-05 to 5.83E-05 and 2.22E-06 to 5.83E-07 m/s). The groundwater yields in these wells are highly variable , ranging from 18.63 to 46.30 l/s.

6.3 Piezometric analysis of regional groundwater flow

6.3.1 Groundwater flow patterns along the hydrogeologic profile H3"-H3'

The distribution of equipotential contours and flow lines were constructed utilizing the measurements of the average non-pumping water-levels in the following piezometers: P78, P44, P43, WW16, P79, WW17, WW8, WW18, S223 and D739 as shown in Figure 6.2. The major water divide is oriented north to south across the central region of the province. Most of the recharge areas are situated in the central area where the water table is relatively deep. The hydraulic head decreases in all directions from this central region. The concentration of flowing wells (WW8, S311, WW4 and D65, Figure 6.1) along stream valleys indicates that these are zones of converging and upwardly discharging flow.

The dominant flow paths in the Hin Tank Hydrogeologic Province parallel the direction of the creeks, which develop along the major joints and fractures in the Phu Tok hydrogeologic unit. Figure 6.2 illustrates the important cross formational flow that accompanies groundwater movement from the recharge area to the discharge area. Faulting, along the northern province boundary at Ban Nong Khai Nun created fractures and cavities which consequently exhibit marked anisotropy. Groundwater flow is often channeled along these fractures and cavities (Plates 6.1, 6.2 and 6.3). Thus, in addition to topography the geologic structures and fracture pattern of the Phu Tok Formation exert a marked influence on flow patterns.

6.3.2 Groundwater flow patterns along hydrogeologic profile H4"-H4'

Figure 6.3 illustrates the potential distribution across the hydrogeologic profile H4"-H4' based on the measurement of water levels at Ban Huai Toei and Ban Nong Khai Nun. The trajectory of the flow patterns in the vicinity between Ban Huai Toei and Ban Nong Khai Nun were inferred from the geomorphic maps of that area because of the limited numbers of piezometers. However, the hydrogeologic profile across H4''' - H4' is still valid as discussed in Chapter 3 (Ban Nong Khai Nun). Groundwater flow across the shales and sandstones of the Phu Tok unit (Tpt) are controlled by a series of faults along the creek (Huai Chan) and the Chi River and several local and intermediate flow systems are mainly controlled by the undulating topography as well as the impermeable faults.

6.4 Surface evidence

6.4.1 Geomorphic features

Due to lack of piezometers in the central and eastern regions of the province, the recharge and discharge areas for the entire province were mapped by both piezometric analysis in conjunction with the geomorphic mapping as applied for the Chonnabot Hydrogeologic Province. Figure 6.1 shows the resultant of maps of recharge and discharge areas as well as the surface manifestations that are related to the groundwater flow regimes. The series of geomorphic maps including topographic elevation, soil-drainage class, salinity index and land type are illustrated in Figures 5.3 to 5.6. The quantitative relationship among these features are summarized in Figure 6.4. The average non-pumping water-levels in 53 piezometers and wells over the entire province are shown in Table 6.4. The average maximum and minimum water level fluctuation are categorized for an individual range of the topographic elevations as depicted in Figures 6.4 and 5.3. from the figures it can be seen that higher water level fluctuation of about 10 m was found in the recharge area where the topographic elevations range between 180 to 200 m amsl.

Recharge areas of the Hin Tank Hydrogeologic Province cover an area of about 620 km^2 consisting of 80% of the province uplands (elevation >180 m amsl Figure 5.3) and about 97% of the total area is covered by soil with salinity index no. 5 (Figure 5.4). Moreover, about 87% of the total area can be categorized by the land type of high and broad ridges of gentle slope (R) and gently undulating to high level plains (Gu, Figure 5.5).

Discharge areas (480 km^2) comprise 88% of the topographic lowlands (elevation <180 m amsl) and 80% of the following land types: flood plains with gentle to nearly level slope with local salt affected areas (Fp); alluvial plains (A), and relict meander belts of the

Chi River (Rm, Figure 5.5). About 80% of the land has a salinity index no. 4 (high topography, moderately salinised soil) and no. 5 (high topography underlain by rock salt, Figure 5.6 after SSD, 1973b) is frequently found on the lowland slopes. The soil-drainage class for this area is not available at the present study.

6.4.2 Other surface manifestations of groundwater flow

Flowing wells, springs, salt tolerant plants and soap holes are commonly found in the topographic lowlands. Flowing wells with an average yield of 0.5 to 1 l/s are found at Ban Nong Khai Nun (WW4, P2 and P4) in the north, Ban Don Khloi (D839), in the east, Ban Nong Pak Top (S311) in the west and at Ban Nong Nae (D65) in the south (Figure 6.1). Some flowing wells are also found in local depressions at relatively high elevations such as Ban Khon Sak (WW8). Salt tolerant plants (halophytes) comprising: *Azima Sarmentosa* (Nam Phong Do); *Maytenus Mekongensis* (Nam Daeng) and *Gisekia Pharmacoides* (Pak Bia Daeng), are commonly associated with the highly salinised soil found in the paddy fields of Ban Nong Khai Nun. *Pluchea Indica* (Khlue), *Synostemon Bacciformis* (Soy Nok Kao or Ma Fai Doen Ha), *Massia Triseta* (Yar Hua Kai) and *Fimbristylis Hookeriana* (Yar Hua Bo) are also found in naturally swampy areas, i.e., Ban Nong Khai Nun

6.5 Hydrochemistry

The hydrochemical data of the Hin Tank Hydrogeologic Province are tabulated in Tables 6.1 to 6.4. Six samples of rain water: RW8, RW9, RW10, RW16, RW18 and RW19, were collected during July, 1989. They exhibit low TDS contents, ranging between 16 and 38 mg/l, and pH values of 6.30 to 8.20. Hydrochemical classification based on the Piper diagram modified by Galloway and Kaiser (1980) shows the rain water to be in the Ca-HCO_3 facies.

Samples of surface waters were also taken from rivers, swamps and ponds (Table 6.2). The TDS content of the various surface waters range widely between 30 and 7800 mg/l. Samples taken from the Chi River indicate that two main hydrochemical facies which are: Ca-Na-HCO_3-Cl and Na-Cl facies.

6.5.1 Distribution of ionic concentrations and hydrochemical facies of groundwater

Selected chemical constituents of the groundwaters in the Hin Tank Hydrogeologic Province are presented in Table 6.4. The TDS contents increase from less than 500 mg/l in the central region to more than 5000 mg/l in the discharge zones and Mg^{2+}:Ca^{2+} increases from 0.3 to 0.7 (Figures 6.5a and 6.5b) whereas Ca^{2+}:Na^{+}, and $SO4^{2-}$:Cl^{-} decrease from the central region towards the peripheral areas (Figures 6.5c and 6.5d).

The following section pertains to the seven hydrochemical facies which have been identified for the Hin Tank Hydrogeologic Province (Figures 6.6 and 6.7).

Facies 1 calcium-bicarbonate (Ca-HCO_3)

Facies 2 calcium-sodium-bicarbonate (Ca-Na-HCO_3)

Facies 3 calcium-bicarbonate-chloride (Ca-HCO_3-Cl)

Facies 4 calcium-chloride (Ca-Cl)

Facies 8 calcium-sodium-bicarbonate-chloride (Ca-Na-HCO_3-Cl)

Facies 9 sodium-chloride (Na-Cl) and

Facies 10 sodium-sulfate-chloride (Na-SO_4-Cl).

The Ca-HCO_3 facies is dominant in the central region where the TDS contents of the groundwater is less than 500 mg/l. The Ca-Na-HCO_3 and Ca-HCO_3-Cl facies are found in the western and the eastern regions respectively where is TDS ranges between 500 and 2000 mg/l. The Ca-Na-HCO_3-Cl facies, with an average TDS contents of 720 mg/l is found only in the paddy field at Ban Nong Khai Nun. Finally, Na-Cl facies is found where groundwater TDS ranges from 1154 to 44300 mg/l occurs along the flood plain of the Chi River in the west, north and northwest areas of the province.

6.6 Groundwater flow patterns and systems determined by field evidence

The major water divide is oriented north to south across the central region of the province (Figures 6.1, 6.2 and 6.3). Most of the recharge area is located at the center where the hydraulic head is relatively high. The hydraulic head decreases radially. The average depth of the water table in the recharge areas, is 5 to 15 m below the ground surface, much deeper than in the discharge areas, where it is generally less than 1.5 m below the ground surface. As a result of hydrogeologic mapping and water level monitoring in the Hin Tank Hydrogeologic Province, eleven flow systems were identified, namely:

- Ban Phai regional system (CR1)
  - Ban Thang Phat intermediate system (CI1-1)
    - Ban Huai Chang local system (CL1-1)
    - Ban Kham Pom local system (CL1-2)
- Kosum Phisai regional system (CR2)
    - Ban Khon Sak local system (CL2-1)
    - Ban Bo Luang local system (CL2-2)
- Huai Toei regional system (CR3)
  - Ban Nong Khai Nun intermediate system (CI3-1)
    - Hin Tank local system (CL3-1)
    - Tha Phra local system (CL3-2)

Where: C represents the Hin Tank Hydrogeologic Province, R, I and L are Regional, Intermediate and Local flow systems respectively.

Three main regional flow systems are: Ban Phai (CR1), Kosum Phisai (CR2) and Huai Toei (CR3). The Ban Phai regional flow system (CR1) is characterized by a westerly flow pattern, recharging in the water divide area at the center of the province, and discharging in the low plain of the Chi River in the west. The flow path is approximately 15 to 20 km long and with an average maximum flux of 7.34E-07 m/s. The flow system does not extend deeper than 160 m below the ground surface.

The Kosum Phisai regional system (CR2) flows mainly due east from the central recharge area to Huai Taen Creek. It has a longer flow path, 20 to 25 km and with an average maximum flux of 3.39E-06 m/s. The flow depth at the midline area is approximately 170 m below the ground surface.

The Huai Toei regional system (CR3) is active in the northern region and has a little shorter flow path (10 to 20 km). The maximum flow depth is more or less the same as the Ban Phai system and shallower flow depth (160 m) than either the Ban Phai or the Kosum Phisai system. The average maximum flux of 5.04E-06 m/s.

Ban Thang Phat (CI1-1), and Ban Nong Khai Nun (CI3-1) systems are the intermediate systems in the Hin Tank Hydrogeologic Province. They are superimposed on the Ban Phai (CR1), Kosum Phisai (CR2) and Huai Toei (CR3) regional systems respectively. Their flow paths and depths vary from 4 to 20 km and 110 to 120 m respectively. An average maximum flux is variable (6.52E-08 to 2.0E-06 m/s).

The local flow systems are approximately 1 to 5 km long, penetrating to between 20 and 50 m below the ground surface (Figures 6.2 and 6.9).

6.7 Hydrochemical processes

Variations in the hydrochemical facies of these regional flow systems may be caused by several factors: length and rate of flow paths, aquifer mineralogy and fracture patterns. The results of the pumping test at WW4 at Ban Nong Khai Nun indicate that the shales, siltstones and sandstones of the Phu Tok (Tpt) are highly fractured, heterogeneous and anisotropic.

6.7.1 Hydrochemical evolution along flow path CR1-CR1' for Ban Phai regional groundwater flow system (CR1)

Rain waters collected at RW8, RW18 and RW19, within the Ban Phai regional flow system (CR1), contain 16 to 36 mg/l of TDS. The rain water is classified as Ca-

HCO_3 water with a pH range 6.8 to 8.20. Rain water recharges at the central region of the province at well WW18, Ban Khon Sak, and flows downward and westerly towards Ban Kham Pom (WW17) and Ban Thang Phat (WW16) through the shales, siltstones and sandstones of the Phu Tok unit (Tpt), and finally flowing upward in the flood plain area along the Chi River at well P78. The total flow path CR1-CR1' is approximately 20 km long as shown in Figures 6.9 and 6.10a. The cation and anion dominance orders along this flow path are $Ca^{2+}>Na^{+}>Mg^{2+}>K^{+}$and $HCO_3^{-}>Cl^{-}>SO_4^{2-}$ in recharge areas, whereas discharge waters exhibit $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ and $Cl^{-}>SO_4^{2-}>HCO_3^{-}$ (Figure 6.11a). The SiO_2 content decreases along the flow path from 20 to 1 mg/l.

Ca^{2+} increases in concentration from the recharge area towards the discharge area. whereas HCO_3^{-}decreases. The correlation lines for both Ca^{2+} and HCO_3^{-} versus Cl^{-} deviate from the 45° line until $Na^{+}:Cl^{-}$ molar ratio decreases along the flow path from 3.38 to a minimum of 0.75, consequently deviating from the 45° line. The $Na^{+}:Cl^{-}$ ratio rises close to unity in the discharge area (Figure 6.12). The correlation line for SO_4^{2-} versus Cl^{-} initially decreases and subsequently increases with increasing Cl^{-}. This may be due to cation exchange Ca^{2+} ions displacing Na^{+} ions from clays found within the recharge area, additional Ca^{2+} being added to the groundwater by the dissolution of sulfate minerals, such as gypsum and anhydrite.

The ratio of $Mg^{2+}:Ca^{2+}$ is less than 1.00 along the entire CR1-CR1' flow path, however there is a slight initial increase along the flow path. Whereas the ratio of $Ca^{2+}:Na^{+}$ decreases from 4.59 to 0.35 (Figure 6.10a). The $Ca^{2+}:SO_4^{2-}$ ratio is greater than 1.00 and increases downstream. These trends indicate that cation exchange is a dominant chemical process along the flow path.

Calculated saturation indices indicate that the groundwater along the entire flow path CR1-CR1' is undersaturated with respect to dolomite, gypsum, anhydrite and halite. The saturation indices with respect to calcite are obtained at wells WW18 and P78. These saturation indices were calculated assuming an average temperature of 30° C as shown in

Figure 6.14. The maximum TDS content along CR1-CR1' is less than 13155 mg/l at P78 found within the discharge area. The calculated ionic strength of the groundwater increases from 0.0069 in the recharge area to 0.2320 in the discharge areas (Table 6.8).

The main hydrochemical processes along the flow path CR1-CR1' are (Figure 6.11a): dissolution of calcite and silicate minerals in the recharge area, cation exchange with clay minerals in the shales of the Phu Tok unit (Tpt) in the midline area, and finally dissolution of evaporites, gypsum, anhydrite and sylvite in the discharge area. In addition, diffusion of halite from the Mahasarakham unit (Kms) is found in the discharge area. The hydrochemical facies developed in a downstream direction along the flow path CR1-CR1' are: $Ca\text{-}HCO_3 \rightarrow Ca\text{-}Na\text{-}Cl \rightarrow Na\text{-}SO_3\text{-}Cl$. Dissolution of calcite and silicate minerals is dominant in the recharge area. Dissolution of evaporites minerals from the Mahasarakham unit is the major process in the discharge area and calcite is precipitated in water containing TDS greater than 13000 mg/l.

6.7.2 Hydrochemical evolution along flow path CR3-CR3' for Huai Toei regional groundwater flow system (CR3)

Rain waters collected within the confines of the Huai Toei regional flow system (CR3) at RW9 and RW10, contain 17 to 37 mg/l of TDS contents. The rain water is also classified as $Ca\text{-}HCO_3$ water with a pH of 6.3 to 7.60. Groundwater recharge occurs in the central region of the province (well PWLR) at Ban Huai Toei, and flows downward, towards the north and discharging upwards at Ban Nong Khai Nun (WW4) and at Huai Chan (P5). The total flow path approximately 12 km long as shown in Figures 6.10b and 6.11b. The dominant ions along the flow path (Figure 6.11b) have similar trends to the flow path CR1-CR1'. Ca^{2+}, HCO_3^- and SiO_2 initially increase and then decrease along the flow path. These ions may be added to the recharge water by dissolution of sandstones and alteration of clay minerals found in the shales of the Phu Tok matrix. The groundwater composition varies between the recharge area and discharge area due to the dissolution of carbonate minerals and alteration of clay minerals encountered along the downward flow path. Calcite precipitation may occur at well WW4 in the discharge area where saturation index with respect to calcite is equal to 0.0 (SIc, Figure 6.14). The groundwater TDS contents increase downstream from 89 mg/l in the discharge area to 1159 mg/l found in the discharge area.

The stoichiometric balance between ions, if present, can be represented for selected ion pairs using X-Y plots to examine possible geochemical processes . If Ca^{2+} $/(HCO_3^-+SO_4^{2-})$ and Na^+/Cl^- exhibit a ratio close to 1.0 this indicates that neither ion exchange nor sulfate reduction are significant, instead a simple solution process may be taking place. For the groundwater along the flow path CR3-CR3', the Na^+:Cl^- molar ratio decreases slightly downstream along the flow path but remains close to unity (Figure 6.12) the same as for all groundwater in the regional systems of this province. The ratio of Ca^{2+} $/(HCO_3^-+SO_4^{2-})$ is deviates slightly from 45° (Figure 6.13). Both Ca^{2+} and Mg^{2+}, and also HCO_3^- versus Cl^- initially increase in the recharge area and then decrease in the discharge area. Ca^{2+} is removed from groundwater by the precipitation of carbonate minerals.

Saturation indices indicate undersaturation with respect to dolomite, gypsum, anhydrite and halite for all groundwater samples along the flow path CR3-CR3'. The calculated ionic strengths of the groundwater increase from 0.0016 in the recharge area to 0.0212 in the discharge area (Table 6.8).

The hydrochemical processes operating along this flow path are simple. Dissolution of calcite and silicate minerals is dominant in the recharge areas while dissolution of evaporites within the Mahasarakham unit is major process in the discharge areas. With increasing TDS contents (>1100 mg/l) calcite is precipitated. The main geochemical processes are simple solution along the flow path with mixing with water from the local flow systems in the discharge area which can be clearly seen on expanded Durov diagram plot (Figure 6.15).

Huai Toei regional system (CR3), is active in the northern region, and exhibits a shorter flow path (10 to 20 km) and deeper flow depth (170 to 180 m) than either the Ban Phai or the Kosum Phisai regional flow system (CR2) and has a relatively high average maximum flux of 3.94E-06 m/s. The water residence time and the short duration of water-rock interaction may explain the low TDS content of groundwater in the discharge area of the Huai Toei regional flow system.

The concentrations of flowing wells (WW8, S311, WW4 and D65) along stream valleys indicate that these are zones of converging and upwardly discharging flow. The dominant flow paths in the Hin Tank Hydrogeologic Province are oriented parallel to the directions of the creeks which have developed along the major joints and fractures of the Phu Tok unit. Flow is also directed towards the southeast along the plunge of the synclinal axis.

From the field observations groundwater flow in the Hin Tank Hydrogeologic Province illustrates three dimensional flow system just like the Huai Yai and Chonnabot Hydrogeologic Provinces. The major controlling factors are fractures and faults and type of topographic terrain found throughout the province. Whereas, the hydrochemistry of the aquifer, is affected by the lithology of the Tpt and Kms units. The hydraulic parameters of the Tpt unit are highly variable.

6.8 Mathematical model

6.8.1 Model design and input parameters

A three-dimensional mathematical model was used for the theoretical investigation of flow systems in the Hin Tank Hydrogeologic Province. Figure 6.16 shows the model configuration that comprises 50 nodes in the x (east-west) direction, with a spacing of 1000 m, and 44 nodes in the y (north-south) direction with a spacing of 1000 m and 12 nodes in the z vertical section with a spacing of 20 m. Vertical boundaries extend to the base of the model along all the edges. The western and northern boundaries which are simulated as no flow boundaries are coincident with the Chi River. The eastern and southern boundaries are also simulated as no flow boundaries coincident with Huai Taen and Huai Kut Chuak Creeks respectively. The aquifer thickness assigned to the model is an estimate based on the stratigraphic sections and lithologic logs from shallow water wells, most of which do not penetrate the full extent of the Phu Tok Formation. The hydraulic conductivity values are calculated based on pumping test analysis and considering partially penetrating wells. The rock salt unit (rs) is assumed to form an impermeable boundary at the bottom of the model. The basal boundary is located at an elevation of 20.0 m amsl.

The water table configuration which forms the upper boundary was approximated to the ground surface. The correlation between the water table depths and well depths to the topographic elevations, indicates that the average depth of the water table below the ground surface ranges between 5 and 15 m in recharge area to less than 1.5 m in the discharge area (Figure 6.8). The initial values of hydraulic head assigned to nodes along the upper boundary were 10 m below the ground surface elevations in recharge area and 5 m in the discharge area. Simplified hydrostratigraphic section of the model was constructed from the hydrogeologic profiles H3"-H3' and H4"-H4'. The hydraulic conductivity values assigned to nodes within the Phu Tok unit in the x, y and z directions are indicated in Figure 6.17. Horizontal isotropy (equal hydraulic conductivities in the x and y directions) is assumed for all hydrogeologic units. Vertical hydraulic conductivities were assigned to be 2 to 3 orders of magnitude less than the horizontal hydraulic conductivities for the Phu Tok Formation and Quaternary sediments.

6.8.2 Model calibration and sensitivity analysis

The calibration procedure is based on a best fit of values of the simulated versus measured hydraulic head and on the resulting recharge-discharge patterns. The distribution and magnitude of hydraulic conductivity values for the Phu Tok Formation were varied for different simulations, until a reasonable match was obtained between the measured and calculated head at the 28 reference nodes along the aquifer. In the final simulation a "fair" correlation, with an error between 10 m and -7 m and a root mean squared error (RMS) of 4.48 m was obtained (Figure 5. 18j and Table 6.11).

Anomalies were found in two areas; Ban Khon Sak (WW18), and Ban Tha Phra (PWDF). The hydraulic heads calculated from the model for these areas are relatively high (about 10 m). This may be due to two factors namely: in wells located in high topographic elevations such as at Ban Khon Sak (WW18), the water table may be suppressed with respect to the topographic elevation. The correlation between observed and simulated hydraulic head is generally better at lower topographic elevations. At Ban Tha Phra (PWDF), the anomalously high simulated head (+8 m) may be due to associated fracturing or faulting of the aquifer and from pumping of the wells. A marked water table decline has been observed by long term monitoring in piezometer no. C32KK12 at Ban Tha Phra during the period 1977 to 1989, as depicted in Figure 6.19. The average rate of decline of the water table in Ban Tha Phra was about 0.60 m/a. The fall of the water table is probably due to over exploitation of groundwater for utilization in the dye and soft drink factories at Ban Tha Phra.

In general the final simulations of the Hin Tank model provide fair agreement with the field data for this natural hydrogeologic province. However due to the complexity of the province and limitation of hydraulic parameters such as the distribution of hydraulic conductivity values (in the x, y and z directions), boundary conditions, it is necessary to examine the possible limitations of the input parameters of the model by sensitivity analysis.

A sensitivity analysis is performed by varying the degrees of anisotropy between hydraulic conductivities in the x and y directions, and between hydraulic conductivities in the x or y to z directions, and changing the position of the basal impermeable boundary of the model. The assigned Kx to Ky ratios are 100:1, 10:1, 5:1, 1:1 and 1:10. The results of the observed and modeled hydraulic head are shown in Table 6.11 and Figure 6.18. The best fit equipotential lines suggest that Kx to Ky values of 5:1 and 1:1 are probable.

The second step of the sensitivity analysis is to vary the ratios of vertical (Kz) to horizontal (Kx or Ky) hydraulic conductivities. The ratios of 1:1000, 1:100, 1:10, 1:1 and 1:0.1 were tested. The results of these simulations (Table 6.11) show that the magnitude of hydraulic head, and recharge and discharge rates are more sensitive to permeability anisotropy than to the flow pattern of the recharge and discharge areas. Reasonable degrees of anisotropy (Kx or Ky to Kz) for the Phu Tok Formation are 1:0.1 to 1:0.01 which yield a root mean squared error (RMS) between measured and simulated hydraulic head of less than 5 m. Assigned Kz magnitudes beyond these ranges result a RMS exceeding 20 m (Figure 6.18) and non matching values of hydraulic head and the distributions of recharge-discharge areas.

Due to the lack of deep well information (no wells penetrate deeper than 250 m below the ground surface), the elevation of the basal impermeable boundary of the model is in question. However, the third step in the sensitivity analysis is to vary the position of the basal impermeable bed. This was simulated by moving the basal boundary from the rock salt bed located at 20.0 m elevation amsl to -800 m amsl. According to the conceptual models in Figures 6.2 and 6.3, the lower elevation, which corresponds to the lowest stratigraphic unit of the Khorat Group, is the conglomeratic limestone of the Huai Hin Lat Formation (Chonglakmani, and Satayarak, 1978). Hydraulic conductivity values of rock salt bed (rs), Mahasarakham (Kms), Phu Phan (Kpp), and Jurassic Formations (Jsk, Jpw and Jpk) were assigned, based on the results of pumping tests as shown in Figures 6.17a and 6.17b. These simulations do not affect the distribution of hydraulic head that appears insensitive to the choice of a basal impermeable boundary. The steady state simulations of the Hin Tank Hydrogeologic Province are useful procedures to quantify the natural water balance of the province.

6.8.3 Flow systems determined by numerical simulations

The magnitudes of hydrogeologic parameters were determined by numerical simulations, and then comparing the simulated values with those estimated by the piezometric analysis and field mapping techniques (Table 6.12).

Overall the parameters calculated by field and simulation techniques do not compare favorably as noted in the Huai Yai Hydrogeologic Province. This may be due to the fact that the fracture pattern of joint and faults is a major controlling factor of the groundwater flow regime in the Hin Tank Hydrogeologic Province.

Chapter 7: Groundwater resources evaluation in hydrogeologic provinces

7.1 Characteristics of hydrogeologic provinces

The groundwater regime in the Khon Kaen Drainage Basin has been characterized for several study areas, i.e., Ban Nong Khai Nun, Huai Yai, Chonnabot and Hin Tank in Chapters 3, 4, 5 and 6 respectively. **A hydrogeologic province** is defined for the present purpose as a geographic region characterized by uniform physiographic, geologic and hydrologic conditions, as described by quantifiable parameters. The measurable physical and chemical properties of the three hydrogeologic provinces are summarized in Tables 7.1 and 7.2. The typical characteristics of these hydrogeologic provinces are representative of the groundwater flow regime in a **an anticline-syncline** (Huai Yai), **an anticline-faulted block** (Chonnabot), and **a faulted block** (Hin Tank).

The hydrogeologic environments in these three hydrogeologic provinces are the function of climate, topography and geology. The distribution of annual rainfall over the entire Khon Kaen Drainage Basin ranges from 1000 to 1200 mm resulting from their similarity in the climatic condition. The topography and geology in these provinces affect the patterns and values of their hydrogeologic environmental parameters, namely, distribution of recharge-discharge areas, recharge rates, flow pattern geometry and hydrochemistry.

The Huai Yai Hydrogeologic Province is areally bounded by surface water divides along the Phu Meng and Nong Lup ridges located in the west and north. The southern and eastern boundaries are confined by the fault line and fault zones (presumably vertical planes) where the Na Klang Creek and the Chi River exist. The Chonnabot and Huai Yai Hydrogeologic Provinces are characterized as faulted block provinces. The areal boundaries of the Chonnabot Hydrogeologic Province is a no flow boundary defined by the fault lines of the Na Klang and Sai Kai creeks in the north and west, and the southern and eastern sides respectively. The areal boundaries of the Hin Tank Hydrogeologic Province are bounded by four fault lines and fault zones on which the Chi River Bed has developed in the west and north, and the Huai Taen and Huai Kut Chuak creeks existing in the east and south respectively.

7.1.1 Topographic effects

The configuration of the potentiometric surface of the Khon Kaen Drainage Basin shows strong correlation with topography. The regional head gradient is generally inclined towards the central lowlands of the basin along the flood plains of the Chi and Phong rivers, the same direction as the regional land surface slope. Local head gradients exist between watershed divides and adjacent stream valleys, where down dip flow is partly deflected toward stream valleys. The distribution of flowing wells supports the probability that stream valleys are zones of converging flow. The rolling hill and undulating relief form a sinusoidal land surface that normally exists at the higher elevations (>190 m amsl), whereas the gentle slope or flat topographic expression is commonly found in the central region of the Huai Yai Hydrogeologic Province. The prominent sinusoidal land surface exists in the Chonnabot and Hin Tank Hydrogeologic Provinces.

Topographic influences on the water levels in the three hydrogeologic provinces decrease with increasing aquifer confinement at depth. Correlation among the water levels, well depths and land elevations suggested that the arithmetic average water level depths are 5 to 15, 4 to 18 and 5 to 15 m below the land surface in the recharge areas for the Huai Yai, Chonnabot and Hin Tank Hydrogeologic Provinces respectively. On the contrary, the average depths of water levels in the discharge areas are generally less than 1.5 m below the ground surface for these three provinces.

The regional flow systems in the three provinces are strongly influenced by the regional topographic expressions. The local and intermediate flow systems in the Huai Yai and Chonnabot Hydrogeologic Provinces are mainly controlled locally by topography and dips of the beds (anticline and synclines), while the local and intermediate flow systems in the Hin Tank Hydrogeologic Province are controlled by the distribution of fractures (joint sets) rather than the local topography.

The distribution of recharge and discharge areas in the Huai Yai Hydrogeologic Province, were mapped based on the piezometric analysis and the integration of piezometric and geomorphic features. The patterns of recharge and discharge areas were confirmed by a three dimensional steady state model. About 67 % of the areal area of the Huai Yai Hydrogeologic Province (830 km^2) is occupied by the discharge areas. On the contrary, about 68 % and 57 % of the Chonnabot (176 km^2) and Hin Tank (1110 km^2) Hydrogeologic Provinces are occupied by the recharge areas respectively.

7.1.2 Geologic effects

Geology also influences potentiometric surface configuration. Hydraulic head and hydraulic gradients decrease down structural dips of beds and anticline and syncline axes in the Chonnabot and Hin Tank Hydrogeologic Provinces. The fractures along the bedding planes and dip of the sandstones, siltstones and shales of the Phu Tok unit strongly control the flow direction particularly the areas near the province boundaries such as at Ban Nong Khai Nun and Ban Tha Phra. In the Huai Yai and Chonnabot Hydrogeologic Provinces, the potentiometric surface in both areal and vertical views shows no clear response to the heterogeneities of the hydrogeologic units of the sandstones, siltstones and shales of Kpp, Kkk and Kms hydrogeologic units. Their effects are probably masked by topography and structure. Moreover, regional hydraulic head data are insufficiently sensitive to demonstrate effects of the aquifer heterogeneity on flow patterns for either field mapping or by modeling.

Cross-formational flow is a regionally significant aspect of groundwater movement in the three hydrogeologic provinces. The hydraulic conductivities of hydrogeologic units in the Khon Kaen Drainage Basin were determined by pumping tests which considered partial penetration wells of pumped and observation wells. The tests show the significant variations in values of horizontal hydraulic conductivity (Kx, Ky) and the values of vertical hydraulic conductivity (Kz). The degrees of anisotropy (Kz to Kx or to Ky) of the sandstones and shales of the Mahasarakham units (Kms, in the Huai Yai Hydrogeologic

Province) and sandstones, siltstones and shales of the Phu Tok unit (Tpt, Hin Tank Hydrogeologic Province) are 0.0001 to 1.000 and 0.001 to 1.000 respectively. The results of 3-D modeling for the Huai Yai and Hin Tank Hydrogeologic Provinces obtained a reasonable match with the results of the pumping test analysis.

The Khon Kaen Drainage Basin was subject to compressional orogeny, followed by uplift and erosion from the early Tertiary to the present (Kozar et al, 1992). The sandstones and siltstones of the Tertiary Phu Tok Formations were strongly effected by the orogeny. Strike slip faults and extension joints can be observed in the outcrop along the stream bed of the Chi River, e.g., Ban Nong Bua De Me and can also examined by the Televiewer while drilling at Ban Nong Khai Nun. The offsets of the hydrogeologic units and lineaments of surface manifestations i.e., soap holes and salt tolerant plants were recognized. The trellis pattern of streams and creeks is common in the Hin Tank Hydrogeologic Province. Some lineaments of trees (at Phalan Hin Keang) illustrate the orientation of joints and fractures. Moreover, the simulations of the 3-D model for the Hin Tank Hydrogeologic Province are very difficult to calibrate under the assumption of equivalent porous media of the Phu Tok aquifer.

7.1.3 Groundwater systems

The scales of groundwater flow systems, local, intermediate and regional, were mapped based on the monitoring of water levels and hydrogeologic conditions in the three hydrogeologic provinces. In Huai Yai Hydrogeologic Province, three regional flow systems (AR1, AR2 and AR3) are active and flow in different directions (to the southwest, north, and to the south from the recharge areas). The effective flow depths range from 150 to 170 m below the land surface with variable flow paths (8 to 40 km). In the Chonnabot Hydrogeologic Province, there is only one regional flow system (BR1) active in the province flowing in a radial direction from the water divide located in the central region towards the province boundary. The effective depth of BR1 (170 m below the ground surface) is generally deeper than the regional flow systems in the Huai Yai it flows but a shorter path (8 to 10 km). Three main regional flow systems were differentiated in the Hin Tank Hydrogeologic Province, CR1, CR2 and CR3, the directions of flow are discrete (due west, east and north) with the topography and fractures effectively controlling the regional flow paths. The effective flow depths are more or less the same as AR1, AR2 and AR3. The flow paths range from 10 to 25 km.

There are several intermediate and local flow systems which are superimposed on the regional systems in the three hydrogeologic provinces. Three intermediate systems, AI1-1, AI2-1 and AI3-2, were differentiated in the Huai Yai Hydrogeologic Province. Their effective flow depths ranges approximately 60 to 80 m below the ground surface with flow paths of 5 to 20 km. The flow directions are parallel to the regional flow paths. Two intermediate flow systems, CI1-1 and CI3-1, are superimposed on the three region systems in the Hin Tank Hydrogeologic Province. Their effective depths (110 to 120 m) are generally deeper than the intermediate systems in the Huai Yai Province.

Several local flow systems were mapped in all three provinces, all are active with their effective depths less than 50 m below the ground surface and have a short flow path (0.5 to 2 km). However some local flow systems in the Hin Tank Hydrogeologic Province have local flow paths up to 8 km. The local flow systems are mainly controlled by local topographic elevations and fracture patterns.

7.1.4 Hydrochemistry

Mapping and graphing variations in the concentrations of individual constituents as well as total dissolved solids delineate spatial groundwater compositional changes. Identifying specific sequences of reactions that can account for observed hydrochemical patterns is helpful in verifying regional flow patterns inferred from piezometric analysis. The dominant ions in recharge and discharge areas along the regional flow paths within the three provinces along the entire flow trajectories have a similar pattern to: $Ca^{2+}>Na^{+}>Mg^{2+}>K^{+}$and $HCO_3^{-}>Cl^{-}>SO_4^{2-}$ in recharge areas, whereas discharge waters have $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ and $Cl^{-}>SO_4^{2-}>HCO_3^{-}$.

The most prominent hydrochemical facies in the Huai Yai Hydrogeologic Province is Na-Cl water occupying more than 60 % of the province. However, Ca-HCO_3, and Ca-Na-HCO_3 facies cover more than 60 % of the Chonnabot Hydrogeologic Province. About 75 % of the Hin Tank Hydrogeologic Provinces is Ca-HCO_3 and Ca-HCO_3-Cl. Local groundwater flow systems have relatively low TDS contents but a diverse composition when considering all three provinces.

Ionic concentrations of groundwater samples along the regional flow systems within the three hydrogeologic provinces are undersaturated with respect to gypsum, anhydrite and halite. The major hydrochemical processes along the regional flow paths in the Huai Yai Hydrogeologic Province are: dissolution of calcite, dolomite and silicate minerals in recharge areas and dissolution of evaporite minerals (carnallite, sylvite, halite, anhydrite and gypsum), reverse ion exchange and sulfate reduction and mixing in the discharge areas.

Dissolution of calcite and silicate minerals in the recharge area, dissolution of evaporites, and diffusion of halite from the Mahasarakham unit are the main hydrochemical processes along the regional flow path in the Chonnabot Hydrogeologic Province. The hydrochemical processes in the Hin Tank Hydrogeologic Province operating along the regional flow systems are relatively simple. Dissolution of calcite and silicate minerals is dominant in recharge areas and dissolution of evaporites in the Mahasarakham unit is the major process in discharge areas. With increasing TDS contents (>1100 mg/l) calcite is precipitated.

7.1.5 Surface manifestations of groundwater flows

The classification of flow systems in the Huai Yai Hydrogeologic Province indicates that the regional systems exert the strongest influence on surface manifestations and geomorphic features in the major discharge areas, a result likely due to the fact that regional systems persist over relatively large areas and experience extensive water-rock interaction due to a long flow path and low average magnitude of flux.

In order to locate and identify recharge and discharge areas, where topographic relief is not pronounced and no wells or piezometers exist, other geomorphic features such as: soil-drainage class, soil salinity index, vegetation, or surface water quality may be used as mapping tools. A program of mapping these phenomena was applied in each of the three hydrogeologic provinces. The results of hydrogeologic mapping show that in the Huai Yai Chonnabot and Hin Tank Hydrogeologic Provinces, geomorphic features are reliable indicators of recharge and discharge areas as tabulated in Table 7.2.

7.2 Groundwater balance

Evaluation of groundwater resources involves identifying and mapping of the aquifers, determining quantitative hydrologic properties through aquifer testing and predicting sustainable well yields based on the hydraulic data. For groundwater resources development, this analysis must also include an assessment of the possible impact on the existing groundwater flow regime in order to achieve the optimal development of groundwater resources. Therefore, one of the objectives of establishing the Khon Kaen Drainage Basin research project, was an evaluation of the subsurface component of the hydrologic cycle with emphasis on parameters such as recharge, discharge, and natural yield for the hydrogeologic provinces.

7.2.1 Natural basin yield

The natural basin yield is a measure of the dynamic flow through a groundwater basin. It can be estimated from a quantitative interpretation of the regional groundwater flow patterns obtained as solutions to an appropriate mathematical model. On the basis of simulated recharge-discharge maps as shown in Figures 4.27, 4.28, 6.21 and 6.22 for Huai Yai and Hin Tank Hydrogeologic Provinces respectively, it is possible to calculate the total quantity of recharge in the two hydrogeologic provinces. Similarly, one can calculate the total quantity of discharge as the provinces have no groundwater outflow. For steady state groundwater flow regime, recharge is equal to discharge and also equal to natural basin yield (Freeze, 1967). The quantitative values of the natural basin yield for the Huai

Yai and Hin Tank Hydrogeologic Provinces were obtained by calculating the water level fluctuations in the selected piezometers. The hydrographs of monitoring water-level in the Huai Yai, Chonnabot and Hin Tank Hydrogeologic Provinces are shown in Figures 7.1, 7.2 and 7.3 respectively. The methodology and assumptions used in the analytical estimation of the hydraulic parameters have been discussed in section 2.4. The results of calculations are tabulated in Tables 7.3, 7.4 and 7.5.

The hydrologic budget is a quantitative statement of the balance between gain and loss of water from a hydrogeologic province over a specified period of time. The average annual water balance equation at steady-state, modified from Freeze (1967), Jamieson and Freeze (1983) and Yean (1988) for the Huai Yai and Hin Tank Hydrogeologic Provinces, is:

$$P = Qs+Qg+Et \quad \text{...} 7.1$$

and

$$Et=E+E'+E'' \quad \text{...} 7.2$$

where: P is average annual precipitation; Qs is the surface water component of average annual runoff due to precipitation; Qg is the groundwater component of the average annual runoff; Et is the evaporation and evapotranspiration; and E is the evaporation from surface water; E' and E" are the evapotranspiration from irrigated and unirrigated crops respectively. Equation 7.2 is valid for an undeveloped hydrogeologic province where there is no change in storage and no outflow of groundwater.

On the basis of calculated recharge rates in the Huai Yai and Hin Tank Hydrogeologic Provinces in Figures 4.7, 4.28, 6.22 and 6.23, it is possible to calculate the total annual quantity of recharge in these hydrogeologic provinces as shown in Table 7.6. Surface water components of average annual runoff due to precipitation (Qs) and evaporation and evapotranspiration (Et) of the hydrogeologic provinces are often difficult to measure in the field. The nearest meteorological station at Amphoe Muang Khon Kaen is located within less than 20 km in radius of these two hydrogeologic provinces, and has a suitable period of record. For the 33-year period, 1952 to 1985, the average annual precipitation at Khon Kaen was 1178.4 mm. The average potential evaporation has been calculated using the method of Thornthwaite (1984). The average annual actual evaporation and potential evapotranspiration are 1784 and 2020 mm respectively (Appendices 7.1 and 7.2).

The water budgets for the Huai Yai and Hin Tank Hydrogeologic Provinces are only preliminary estimations. However, if the hydrologic data are available these budget should be verified for further study and for the future development of groundwater resources development in these areas.

7.3 Groundwater probability

A groundwater probability map represents the anticipated range of the yields for wells completed in aquifers according to standard well construction practices. It does not actually represent expected aquifer yield (Tóth, 1966). Tóth (1966) introduced the concept of 20-year well yield (Qs_{20}) through adaptation of the modified non-equilibrium formula (Cooper and Jacob, 1946) to arrive at:

$$Qs_{20} = \frac{T.H}{c} \qquad \text{7.3}$$

Where T = transmissivity, H = total available drawdown between static water level and the top of aquifer zone, Qs_{20} = maximum flow rates that can be sustained over 20 years without drawdown below the top of the main aquifer penetrated by the well, and c = conversion factor to account for 8 cycles of time and consistency of units. The predictive accuracy of this calculation depends greatly on how representative the transmissivity value is of regional conditions (Garven, 1982). The types of transmissivity data from which the yield points were calculated for the Huai Yai and Hin Tank Hydrogeologic Provinces are indicated in the maps (Appendices 4.1 and 4.2), and values of 20-year yield, transmissivity, and available drawdown are tabulated in Table 7.6.

7.3.1 Huai Yai Hydrogeologic Province

The Qs_{20} estimation is based on the main parameters derived from pumping test and estimation from flow regime and hydrogeologic units. Figure 7.4 is the groundwater probability map of the Huai Yai Hydrogeologic Province. Four yield ranges have been mapped 0.01 - 0.50, 0.50 - 1.00, 1.00 - 5.00, 5.00 - 10.0 and greater than 10.00 l/s. The relatively high yield area (>10.00 l/s) is located in fractured shales, siltstones and sandstones of the Mahasarakham Formation (Kms) in the central and the southeast areas of the province. The groundwater in this region is not suitable for domestic uses due to the high TDS contents (>3000 mg/l). The higher yield ranging between 1.00 and 5.00 l/s is saturated in Quaternary sand and gravel unit (Qsg) and situated in the north or in the vicinity of the Nong Lup Ridge. The relatively low yield of 0.10 - 0.50 l/s is found in siltstones, sandstones and conglomeratic sandstones of the Phu Phan (Kpp) and Khok Kruat (Kkk) units to the west in the vicinity of the Phu Meng Ridge.

7.3.2 Hin Tank Hydrogeologic Province

Figure 7.5 represents the groundwater probability map of the Hin Tank Hydrogeologic Province. The average yield of wells in the sandstones, siltstones and shales of the Phu Tok unit (Tpt) are based on the results of pumping tests and the lithology and flow regime in this province (Appendix 4.2). There are 4 yield ranges that have been mapped namely: 0.01 - 0.50, 0.50 - 1.00, 1.00 - 5.00, 5.00 - 10.0 and greater than 10.00 l/s. It is clearly seen that the yields of wells in the Phu Tok Formation are quite variable. The lowest yield (0.50 - 1.00 l/s) is located in the central region or in the recharge areas. In the west, east and south of the province, the average yield ranges approximately from 1.00 - 5.00 l/s and is also found locally in the lower topographic areas in the central region. The trend of relatively higher yield of 5.00 - 10.00 l/s were mapped in the northern region, while the higher yield (>10.00 l/s) is located in the northwest of the province at Ban Tha Phra. There are some observations that can be made from this mapping, the yield of wells in this province may be controlled by the structures of the aquifers (fractures density) and recharge and discharge areas.

7.4 Application of "hydrogeologic province" concept to groundwater resources exploration and development in Northeast, Thailand

7.4.1 Population and land utilization in the Khon Kaen Drainage Basin

By the end of 1992, there were a total of 1,691,046 registered persons living in the Khon Kaen Province of which 341,030 persons live in the Amphoe (district) Muang. The population density in the town or municipal area and in the rural area of the Khon Kaen province are about 2,500 and 128 persons per square kilometer, respectively (National Statistical Office, 1992). The population in the Huai Yai and Hin Tank Hydrogeologic Provinces are estimated to be 447,270 persons (341,030+106,240 (128 x 830 km^2)) and 144,800 persons (128 p/km^2 x1100 km^2) respectively based on the rural population density of the Khon Kaen Province.

The land uses in the Khon Kaen Drainage Basin generally are: paddy cultivation (40%), field crops and fruit trees (18%), woodlands (11%) and others (31%) (National Statistical Office, 1986). The main crops are paddy, cassava, kenaf, maize and sugarcane.

7.4.2 Water requirement in the Khon Kaen Drainage Basin

The water requirement in the Khon Kaen Drainage Basin generally consists of domestic, agricultural, livestock and industrial uses.

The domestic water requirement for the rural area was estimated by Yean (1988) based on a water requirement of 250 liters per person per day. The total water requirement of the Khon Kaen Drainage Basin is approximately:

Domestic requirement = 1.34E+10 l/a
Livestock requirement = 1.4E+08 l/a
Agricultural requirement = 1.03E+11 l/a
Others i.e., small scale industries = 2.68E+10 l/a

Total requirement =1.43E+11 l/a

The total water supplied to the area in 1982 was 7.5E+09 l/a (National Statistical Office, 1986). This leaves a net deficit of 1.36E+11 l/a which must come from rain water and groundwater.

The natural basin yields which are estimated for the Huai Yai and Hin Tank Hydrogeologic Province (Table 7.1) are approximately 3.04E+03, 3.36E+02 and 4.12E+03 l/s (or 9.59E+10, 1.06E+10 and 1.30E+11 l/a) respectively. By considering both quantity and quality of the groundwater resources in these provinces, approximately 40 %, 60 % and 75% of the natural basin yields of the Huai Yai, Chonnabot and Hin Tank Hydrogeologic Provinces are occupied by the potable groundwater (TDS < 2000 mg/l). Therefore the potable groundwater resources for the Huai Yai, Chonnabot and Hin Tank Hydrogeologic Provinces are about 3.84E+10, 6.36E+09 and 9.75E+10 l/s respectively. However, groundwater for the whole Khon Kaen Drainage Basin can be utilized for domestic, livestock and conjunctive uses of surface water and small scale industrial uses.

Chapter 8: Summary and conclusions

8.1 Summary

8.1.1 An aquifer system in broad or open hydrogeologic provinces, like Huai Yai, Chonnabot and Hin Tank Hydrogeologic Provinces, is definitely an unconfined aquifer systems, because most water level configuration is a subdued replica of regional topography. Therefore groundwater movement in these Hydrogeologic Provinces is induced by gravity driven force.

8.1.2 Geomorphic features, topography, soil-drainage class, soil type, soil salinity index, land type and quality of surface water, which are indirectly related to various parameters of groundwater regimes such as recharge areas, discharge areas, water levels and flow systems, can be used as practical tools in mapping the distribution of groundwater recharge and discharge areas. However, care is needed, these geomorphic features should be integrated rather than used as a single feature. The least reliable feature in mapping distribution of recharge and discharge areas is the soil salinity index map. However, the salt tolerant plants, salt crust and other features, i.e., termite mounds and salt harvesting sites are good indicators of discharge areas especially in the Huai Yai Hydrogeologic Province. The dominant salt tolerant plants commonly found in discharge areas in the Huai Yai, Chonnabot and Hin Tank Hydrogeologic Provinces are listed as follows:

Huai Yai	**Chonnabot**	**Hin Tank**
Azima sarmentosa (Nam Phong Do, Plate 4.3)	*Azima sarmentosa* (Nam Phong Do)	*Azima sarmentosa* (Nam Phong Do)
Gisekia pharmacoides (Pak Bia Daeng, Plate 4.4)	*Maytenus mekongensis* (Nam Daeng)	*Gisekia pharmacoides* (Pak Bia Daeng)
Maytenus mekongensis (Nam Daeng, Plate 4.5)		*Maytenus mekongensis* (Nam Daeng)
Pluchea indica (Khlue, Plate 4.6)		*Pluchea indica* (Khlue, Plate)
Synostemon bacciformis (Soy Nok Kao or Ma Fai Doen Ha, Plate 4.7)		*Synostemon bacciformis* (Soy Nok Kao or Ma Fai Doen Ha)
Massia triseta (Yar Hua Kai, Plate 4.8).		*Massia triseta* (Yar Hua Kai).
		Fimbristylis Hookeriana (Yar Hua Bo, Plates 3.6 and 3.7)

8.1.3 Groundwater divides in the three hydrogeologic provinces are coincident with surface water divides and situated at the fault lines and /or fault zones along the Chi and Phong rivers.

8.1.4 Regional geologic structures namely, faults, anticline and syncline, fractures (joints) as well as the hydrostratigraphy of hydrogeologic units play important roles in controlling the genetic characteristics of natural groundwater flow systems in the Khon Kaen Drainage Basin. The regional groundwater flow systems are mainly controlled by topography and faults, whereas vertical and horizontal fractures in the sandstones and shales of the Phu Tok hydrogeologic unit are major controls on the local and intermediate flow systems in the Huai Yai Hydrogeologic Province. Rock permeability due to fractures and/or faults is a controlling factor in the origin and distribution of soap holes or pimple mounds in the regional discharge area at Ban Nong Khai Nun.

8.1.5 Relationships between hydrogeologic units in the Huai Yai, Chonnabot and Hin Tank Hydrogeologic Provinces and groundwater flow systems are generally subtle and difficult to document with regional data. Aquifer lithology particularly shales, siltstones and sandstones of the Mahasarakham hydrogeologic unit (Kms) does influence TDS (especially chloride and sulfate). The lithology of the Khok Kruat hydrogeologic unit (Kkk) in the Huai Yai and Chonnabot Hydrogeologic Provinces also affect the high concentrations of sulfate particularly discharge areas at where the regional groundwater flow upward.

8.1.6 Distribution of the hydrochemical facies of surface water and groundwater in the Huai Yai and Chonnabot Hydrogeologic Provinces is a useful tool in elucidating the distribution of the lithostratigraphy provided there are sufficient data. Due to the limited numbers of stable isotopic compositions (oxygen and hydrogen) of groundwater samples, it is unlikely to be used in defining the regional groundwater flow systems in the Huai Yai Hydrogeologic Province. Yet, the oxygen and hydrogen isotopes show a constant signature along the flow path at Ban Nong Khai Nun. The signature is consistent with the main hydrochemical processes along the local and regional flow systems being the dissolution of evaporites from the Mahasarakham rock salt unit (rs). The high salinity of shallow groundwater is caused by upward flow.

8.1.7 The dominant ions in recharge and discharge areas with in the three provinces along the entire flow trajectories have the same pattern as: $Ca^{2+}>Na^{+}>Mg^{2+}>K^{+}$and $HCO_3^{-}>Cl^{-}>SO_4^{2-}$ in recharge areas whereas discharge waters have $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ and $Cl^{-}>SO_4^{2-}>HCO_3^{-}$.

The most prominent hydrochemical facies in the Huai Yai Hydrogeologic Province is Na-Cl water occupying more than 60 % of the province. Whereas, the Ca-HCO_3, Ca-Na-HCO_3 and Ca-HCO_3-Cl are major facies covering more than 60 % and 75 % of the Chonnabot and Hin Tank Hydrogeologic provinces respectively.

The local groundwater flow systems have relatively low concentrations of TDS contents but relatively diverse compositions, whereas the compositions of the regional flow systems are dominated by the Ca-HCO_3 facies in the recharge areas and the Na-Cl and Na-SO_4-Cl facies in the discharge areas. Most of the groundwater in the Khon Kaen Drainage Basin is undersaturated with respect to gypsum, anhydrite and halite.

The major hydrochemical processes along regional flow paths in the Huai Yai Hydrogeologic Province are: dissolution of calcite, dolomite and silicate minerals in recharge areas and dissolution of evaporites minerals (carnallite, sylvite, halite, anhydrite and gypsum), reverse ion exchange and sulfate reduction in the relatively salinised discharge waters in the central region, and mixing with relatively dilute shallow groundwater or local and intermediate flow systems. Dissolution of calcite and silicate minerals in the recharge area, dissolution and diffusion of evaporites of the Mahasarakham unit are the main hydrochemical processes along the regional flow path in the Chonnabot Hydrogeologic Province. The hydrochemical processes in the Hin Tank Hydrogeologic Province operating along the regional flow systems are relatively simple. Dissolution of calcite and silicate minerals is dominant of recharge areas and dissolution of evaporites of the Mahasarakham unit is the major process in the discharge areas.

8.1.8 Discharge areas along major rivers being coincident with fault lines or fault zones. The Chi River can be characterized as an effluent stream during the Rainy Season (July to October) and as an influent stream during the Winter and Summer Seasons (November to June). As well, groundwater flow direction along the river bank reverses seasonally. Therefore, care must be taken in using chemistry of surface water and shallow groundwater as indicators of defining recharge and discharge areas.

8.1.9 Recharge water in the Khon Kaen Drainage Basin is rainwater, with potential recharge rates estimated by the water level fluctuations of 28 %, 10 % and 22 % of precipitation for Huai Yai, Chonnabot and Hin Tank Hydrogeologic Provinces respectively. The recharge and discharge rates calculated by the steady state 3-D model for Huai Yai and Huai Yai Hydrogeologic Provinces are slightly lower than the water level fluctuation methods. Nevertheless, the distribution of recharge and discharge areas agree well with the piezometric analysis for the Huai Yai Hydrogeologic Province. Whereas, the rates of recharge calculated by the model are somewhat different from the data acquired by field techniques in the Hin Tank Hydrogeologic Province. This may be due to the heterogeneity and anisotropy of the Phu Tok hydrogeologic unit. The differences in recharge rates determined by the field and model techniques for the Hin Tank Hydrogeologic Province may be caused by two reasons: 1) the water-level fluctuations during the Summer and Winter Seasons may be caused by abnormal rainfall events that may cause the overestimation of the recharge rates. 2) the numerical models did not take unsaturated zones in account. As a matter of fact, the Huai Yai Hydrogeologic Province is covered by an extensive Quaternary deposits (loess deposits, laterite and alluvium). These deposits are normally unsaturated with groundwater in the recharge areas and may cause some adverse effects on the recharge rates by the models.

8.1.10 There are two major sources of salinity: 1). rock salts moving upward by regional groundwater and 2) redistribution of saline soil on the ground surface by stream, flood and wind. Distribution mechanisms of driving salinity to ground surface are cross formational groundwater flow and evapotranspiration.

8.1.11 Regional groundwater flow patterns in the three hydrogeologic provinces are strongly three-dimensional. The simulations for solving any particular related problem must therefore use three-dimensional analysis.

8.1.12 The vertical hydraulic conductivities of the hydrogeologic units in the Huai Yai and Hin Tank Hydrogeologic Provinces calculated by the steady state 3-dimensional models agree with the values which were calculated from the pumping tests analysis when considering partial penetrating of pumped wells and observation wells. The degree of anisotropy (Kv/Kh) of the shales and sandstones of the Mahasarakham (in the Huai Yai Hydrogeologic Province) and sandstones, siltstones and shales of the Phu Tok units (in the Hin Tank Hydrogeologic Province) are: 0.1 to 0.001 and 0.1 to 0.01 respectively. The degree of anisotropy between Kx and Ky of the Phu Tok determined from the model are 1 to 10 that are compatible with the pumping test result at Ban Nong Khai Nun.

8.1.13 No single physical property of the hydrogeologic province or groundwater basin is sufficient to explain the groundwater flow patterns and systems and flow paths completely. It is important to recognize that the relative importance of the physical properties changes both spatially and temporally as a result of fluctuating groundwater levels.

8.1.14 It is possible to characterize and distinguish study areas based on physical and chemical parameters of hydrogeologic provinces, and to rank hydrogeologic provinces with respect to groundwater availability or suitability for human consumption based on comparison of the hydrogeologic characteristics. The results of the research indicate that the priority in groundwater development should be concentrated on: 1) Hin

Tank , 2) Huai Yai and 3) Chonnabot Hydrogeologic Provinces with the estimated natural basin yields of potable groundwater (TDS<2000 mg/l) of 9.75E+10, 3.84E+10 and 6.36E+09 l/s respectively.

8.2 Conclusions

8.2.1 Suggestions for future work

8.2.1.1 Characterize recharge mechanisms in Quaternary deposits, e.g. loess and wind blown sand, sand and gravel deposits.

8.2.1.2 Analysis of hydrologic and meteorological data, e.g. rainfall, evaporation and evapotranspiration.

8.2.1.3 Deep well monitoring of water levels and hydrochemistry to determine the deep flow system are essential.

8.2.1.4 Geophysical research (Seismic and logging) is important to investigate heterogeneity (fracture patterns or degree of anisotropy) of aquifers and aquitards.

8.2.1.5 Further field data, boundaries of hydrostratigraphic units, measurement of Kh, Kz of aquifers and aquitards (degree of anisotropy).

8.2.1.6 Paleohydrogeologic study in order to investigate the development of saline water and soils related to land forms and land uses.

8.2.2 Application to this study: development and management of the Northeast Thailand

8.2.2.1 To solve the transient case for groundwater flow regime in the Khon Kaen Drainage Basin, to provide the groundwater storage and salinity patterns for various amounts, and duration of groundwater withdrawal and addition. Origin of groundwater and soil salinity, e.g. salt load by mass transport and geochemical modeling.

8.2.2.2 To use results from foregoing project to enable rational decisions to be made concerning management, and hence to make optimum use of water resources in the Khon Kaen Drainage Basin and other areas.

8.2.2.3 To intensify long-term monitoring of hydraulic potential, groundwater withdrawal, surface water use, surface water flow rates, and the salinity of surface water and groundwater

8.2.2.4 To plan and select the potential waste disposal sites for town planning in consideration of the hydrogeologic environment.

8.2.2.5 To investigate the effects of human construction, e.g., dams, reservoirs on salinity problems to the rice paddy field in Northeast, Thailand.

8.2.3 Future groundwater research in Northeast Thailand: areas in the NE-Thailand should concentrate on the following:

8.2.3.1 Groundwater mapping (hydrogeologic map) using landsat images and/or SPOT to identify the distributions of recharge and discharge areas incorporating geomorphic features, e.g., land uses, terrain etc., and to apply to other areas in NE-Thailand.

8.2.3.2 Establishment of a database system for groundwater resources research in NE-Thailand for other applications e.g., soil and water salinity, salt water intrusion, environmental studies, water supply projects etc. Geographical Information System (GIS) should be employed.

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Table 2.1 Code modification to MODFLOW to calculate fluxes between specified head nodes for three dimensional case (after Stoertz and Bradbury, 1989)

Subroutine SBCF1F

In all of the following line, change .LE to EQ.

```
IF(IBOUND(J-1,I,K).LE.0) GO TO 30
IF(IBOUND(J+1,I,K).LE.0) GO TO 60
IF(IBOUND(J,I-1,K).LE.0) GO TO 90
IF(IBOUND(J,I+1,K).LE.0) GO TO 120
IF(IBOUND(J,I,K-1).LE.0) GO TO 150
IF(IBOUND(J,I,K+1).LE.0) GO TO 180
```

Table 2.2 Data requirements for a groundwater flow model (modified from Moore, 1979 and Anderson and Woessner, 1992)

A. Physical framework

1. Geologic map and cross section showing the areal and vertical extent and boundaries of the system.
2. Topographic map showing surface water bodies and divides.
3. Contour maps showing the elevation of the base of aquifer and confining beds (aquitards)
4. Isopach maps showing the thickness of aquifers and confining beds.
5. Maps showing the extent and thickness of stream and lake sediments.

B. Hydrogeologic framework

1. Water table and potentiometric maps for all aquifers
2. Hydrographs of groundwater head and surface water levels and discharge rates.
3. Maps and cross sections showing the hydraulic conductivity and/or transmissivity distribution.
4. Maps and cross sections showing storage properties of the aquifers and confining beds.
5. Hydraulic conductivity values and their distribution for stream and lake sediments.
6. Spatial and temporal distribution of rates of evapotranspiration, groundwater recharge; surface water-groundwater interaction, groundwater pumping, and natural groundwater discharge.

Table 2.3 Representative specific yield values

(Walton, 1989)

Porous media	Specific yield (Dimensionless)
Peat	0.30-0.50
Sand, dune	0.30-0.40
Sand, coarse	0.20-0.35
Sand, gravelly	0.20-0.35
Gravel, fine	0.20-0.35
Gravel, coarse	0.10-0.25
Gravel, medium	0.15-0.25
Loess	0.15-0.35
Sand, fine	0.10-0.15
Sand, medium	0.15-0.30
Sand, coarse	0.20-0.30
Igneous, weathered	0.20-0.30
Sandstone	0.14-0.40
Sand and gravel	0.15-0.30
Silt	0.01-0.30
Clay, sandy	0.03-0.20
Clay	0.01-0.20
Volcanic, tuff	0.02-0.35
Siltstone	0.01-0.35
Limestone	0.01-0.25
Till	0.05-0.20

Table 3.1 Hydraulic conductivities of aquifers and aquitards in the Khon Kaen Drainage Basin

Lithologic units	Locations and wells	Sources	PT	F	Depth	Kh	Kv	Kv/Kh	Q_{S20}
					(m)	(m/s)	(m/s)		(l/s)
Alluvium (Qal)	Ban Don Bom, KK	2		x	2	1.0E-05 - 1.0E-07	NA	NA	NA
Loess (Qls)	KKU, Airfield	2		x	1 - 2	1.4E-06 - 6.5E-06	NA	NA	NA
Quaternary sand and gravel (Qsg)	PWKS	1	x			2.47E-05	NA	NA	5.66
	PWKC	1	x			2.58E-05	NA	NA	2.84
	ARD Centre	4	x			6.48E-05	NA	NA	NA
Phu Tok (Tpt)	WW3, WW4, W16	1	x		30-150	2.22E-05 - 5.83E-05	2.22E-06 - 5.83E-07	0.1-0.01	18.63 - 46.30
	WW17, WW18, PWLR, S913	1	x		40 -60	4.28E-06 - 3.14E-05	4.28E-08 - 3.14E-07	0.001-0.01	1.11 - 4.51
Mahasarakham (Kms)	WW2, WW7, WW11	1	x		30-150	1.16E-06 - 8.56E-06	1.16E-09 - 8.56E-07	0.001-0.1	1.0 - 12.92
Khok Kruat (Kkk)	PWTW	1	x		60	5.79E-07	1.16E-10	0.0002	0.3
Phu Phan (Kpp)	WW1	1	x		40	3.70E-06	1.11E-08	0.003	1.76
Phra Wihan (Jpw)	Ubolrat Dam, Khon Kaen	3		x	1	1.27E-07	NA	NA	NA
Sao Kao (Jsk)						NA	NA	NA	NA
Phu Kradung (Jpk)	Phu Kiew, Chiaya Phum	4	x		50	1.16E-08 - 8.10E-06	NA	NA	0.35 - 5.79

PT = Pumping Test, F = Field permeability test, Kh = horizontal hydraulic conductivity, Kv = vertical hydraulic conductivity and Q_{S20} = Twenty-year safe yield is estimated in Chapter 7

Souces of information: 1= Wongsawat et al.(1989), 2=Boonsener et al. (1983) , 3= Yean (1989) and 4= Srisuk (1985)

Table. 3.2a Average chemical compositions of rain water in the Khon Kaen Drainage Basin

WELL	Ca	Mg	Na	K	HCO	Cl	SO4	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	Density	FEc	TDS	Deuterium	Oxygen	Water Type
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	gm/cc	µS	mg/l	parts/1000	parts/1000	
RW10	2.40	1.90	1.20	0.50	16.00	0.00	2.40	6.30										17			Ca-HCO3
RW12	24.00	0.10	1.60	0.70	75.00	0.00	2.40	7.60	2.00	2.20					0.30		119	68			Ca-HCO3
RW13	4.80	1.20	1.30	0.50	20.00	3.30	0.00	6.50	3.80								38	21			Ca-HCO3
RW14	22.00	1.40	22.00	8.30	59.00	49.00	6.80	6.50	0.93	1.90							268	141			Ca-HCO3
RW15	12.00	0.80	0.90	0.70	38.00	0.00	1.80	7.50	0.29	2.70							71	38			Ca-HCO3
RW16	8.00	3.30	0.90	0.30	14.00	8.40	3.00	8.50										38			Ca-HCO3
RW18	4.60	0.00	1.00	0.30	16.00	2.10	0.00	6.80										16			Ca-HCO3
RW19	6.60	0.50	1.50	0.70	22.00	0.40	2.20	7.80										26			Ca-HCO3
RW2	16.00	0.30	1.40	0.70	49.00	1.70	4.20	8.20	0.23	1.50							95	50	-48		Ca-HCO3
RW3	10.00	1.20	1.20	0.70	20.00	5.90	1.80	8.70	0.22	2.60							62	38	-47		Ca-HCO3
RW4	7.70	1.90	1.50	0.50	26.00	4.60	1.20	7.70	0.21	2.60							53	33	-46		Ca-HCO3
RW5	12.00	1.10	3.50	0.60	46.00	1.70	2.70	7.70	0.23	3.30							96	48	-39		Ca-HCO3
RW6	15.0	1.4	3.3	0.6	47.0	4.6	7.2	7.2	0.22	0.0		100.0						55			Ca-HCO3
RW7	27.0	0.8	1.7	1.6	86.0	0.0	2.4	7.1	0.39	3.1								79			Ca-HCO3
RW8	7.50	3.50	1.10	1.90	29.00	5.90	1.00	8.20										38			Ca-HCO3
RW9	12.00	1.20	1.10	0.70	41.00	1.30	0.00	7.60										36			Ca-HCO3

Table 3.2b Ratios of cations to chloride of average rain water and groundwater in Khon Kaen Drainage Basin

Area	Type of water	Na/Cl	K/Cl	Ca/Cl	Mg/Cl
Huai Yai					
	Rainwater	1.09	0.2	6.41	0.89
	Groundwater	2.47	0.11	2.68	1.63
Chonnabot					
	Rainwater	0.87	0.01	0.3	2.07
	Groundwater	8.36	0.19	1.93	4.78
Hin Tank					
	Rainwater	1.66	0.51	10.7	1.84
	Groundwater	2.87	0.16	5.34	1.77

Table 3.3 Seasonal chemical compositions of surface water in the Khon Kaen Drainage Basin

Sample No.	Characteristics of stream or river	Rainfal station	Annual rainfall(mm)	Rock lithology	TDS (ppm) ANN	SS	RS	WS	Na+K(epm) ANN	SS	RS	WS	Mg/Ca ANN	SS	RS	WS	HCO3(epm) ANN	SS	RS	WS	SO4(epm) ANN	SS	RS	WS	WATER TYPE
	1. PERENIAL STREAMS																								
	1.1Nam Phong River																								
SW4	upstream	NP	945.70	Khok Krua	133.08	165.00	110.75	123.50	0.96	1.16	0.81	0.90	0.02	0.02	0.02	0.02	1.31	1.59	1.16	1.18	0.05	0.07	0.03	0.06	Ca-HCO3
SW5	upstream	NP	945.70	Khok Krua	89.67	112.50	82.00	74.50	0.71	0.85	0.69	0.59	0.03	0.04	0.02	0.04	1.23	1.62	1.21	0.87	0.07	0.03	0.03	0.18	Ca-Na-HCO3
SW6	downstream	MKK	1255.70	Mahasarakham	102.42	126.00	87.25	94.00	0.71	0.88	0.56	0.70	0.02	0.02	0.03	0.02	1.32	1.64	1.33	0.98	0.05	0.02	0.01	0.14	Ca-Na-HCO3
SW7	downstream	MKK	1255.70	Mahasarakham	175.08	229.50	127.50	168.25	1.82	2.52	1.27	1.66	0.03	0.02	0.03	0.03	1.33	1.65	1.10	1.24	0.04	0.03	0.07	0.01	Ca-HCO3
SW8	downstream	MKK	1255.70	Mahasarakham	122.83	122.00	99.00	147.50	0.91	0.85	0.68	1.19	0.02	0.02	0.02	0.03	1.50	1.61	1.32	1.55	0.08	0.03	0.07	0.16	Ca-Na-HCO3
				AVERAGE	124.62	151.00	101.30	121.55	1.02	1.25	0.80	1.00	0.02	0.02	0.02	0.03	1.34	1.62	1.23	1.17	0.06	0.03	0.04	0.11	
	1.2 Chi River																								
SW14	upstream	CNB	1216.80	Mahasarakham	356.00	526.50	305.50	236.00	4.78	5.51	3.77	4.81	0.05	0.04	0.05	0.05	1.19	1.19	0.95	1.42	0.65	1.38	0.34	0.21	Na-Cl
SW15	upstream	CNB	1216.80	Mahasarakham	443.64	713.50	131.50	500.00	5.10	8.29	1.09	6.21	0.02	0.02	0.02	0.03	1.47	1.75	1.25	1.40	0.36	0.59	0.14	0.34	Na-Cl
SW16	upstream	CNB	1216.80	Mahasarakham	817.83	929.00	717.00	807.50	12.16	12.83	9.54	14.76	0.03	0.03	0.03	0.03	1.11	1.23	1.24	0.87	0.05	0.02	0.21	0.03	Na-Cl
SW18	upstream	CNB	1216.80	Mahasarakham	473.75	854.75	145.50	421.00	5.93	11.66	1.14	4.98	0.02	0.02	0.01	0.02	1.69	2.06	1.26	1.76	0.39	0.65	0.21	0.30	Ca-K-Cl
SW21	downstream	MKK	1149.00	Mahasarakham	496.00	828.00	259.00	400.00																	Ca-Na-HCO3-Cl
				AVERAGE	517.44	770.35	311.70	472.90	6.99	9.57	3.89	7.69	0.03	0.03	0.03	0.03	1.36	1.56	1.17	1.36	0.36	0.66	0.22	0.22	
	1.3 Nam Phong and Chi River (mixed water)																								
SW27	downstream	MKK	1148.50	Phu Tok	141.08	140.75	112.50	170.00	1.11	1.02	0.84	1.48	0.02	0.03	0.03	0.02	1.43	1.65	1.35	1.30	0.14	0.09	0.08	0.23	Ca-Na-HCO3-Cl
SW9	downstream	KS	1093.80	Phu Tok	120.08	144.25	117.00	99.00	1.17	1.22	1.01	1.33	0.02	0.01	0.02	0.03	1.29	1.62	1.36	0.88	0.04	0.04	0.03	0.07	Ca-Na-HCO3-Cl
SW10	downstream	KS	1093.80	Phu Tok	168.58	203.50	103.25	199.00	1.53	2.02	0.72	1.85	0.02	0.02	0.03	0.02	1.45	1.60	1.32	1.43	0.26	0.04	0.03	0.60	Ca-Na-HCO3-Cl
SW11	downstream	KS	1093.80	Phu Tok	171.67	199.25	113.00	202.75	1.39	1.84	0.60	1.73	0.02	0.02	0.02	0.03	1.35	1.63	0.96	1.46	0.13	0.07	0.06	0.24	Na-HCO3-Cl
SW12	downstream	KS	1093.80	Phu Tok	160.67	179.75	120.25	182.00	1.46	1.78	0.90	1.69	0.02	0.02	0.02	0.02	1.40	1.56	1.35	1.30	0.12	0.09	0.06	0.22	Na-HCO3-Cl
				AVERAGE	152.42	173.50	113.20	170.55	1.33	1.58	0.81	1.62	0.02	0.02	0.02	0.02	1.38	1.61	1.27	1.27	0.14	0.06	0.05	0.27	
	2. ARTIFICIAL RESERVOIRS																								
SW1	artificial(dam)	UB	1096.50	Phrawihan S.S.	89.83	98.00	106.75	64.75	0.41	0.41	0.45	0.37	0.02	0.02	0.01	0.03	1.62	1.78	1.88	1.20	0.03	0.02	0.04	0.03	Ca-HCO3
SW2	artificial(dam)	UB	1096.50	Phrawihan S.S.	75.92	89.75	76.25	61.75	0.39	0.40	0.41	0.37	0.02	0.02	0.02	0.03	1.36	1.61	1.36	1.10	0.03	0.03	0.03	0.02	Ca-Na-HCO3
SW3	upstream	NP	945.70	Khok Krua	72.83	82.25	79.00	57.25	0.39	0.39	0.42	0.34	0.02	0.02	0.02	0.03	1.34	1.51	1.42	1.09	0.02	0.02	0.02	0.02	Ca-HCO3
				AVERAGE	79.53	90.00	87.33	61.25	0.40	0.40	0.42	0.36	0.02	0.02	0.02	0.03	1.44	1.63	1.55	1.13	0.03	0.03	0.03	0.02	
	3. DEPRESSIONS AND SWAMPS																								
SW13	natural	CNB	1216.80	Mahasarakham	573.33	1084.50	138.00	497.50	7.48	14.90	1.21	6.35	0.02	0.02	0.01	0.02	1.69	2.09	1.20	1.80	0.40	0.62	0.14	0.43	Na-Cl
SW20	artificial	CNB	1216.80	Mahasarakham	215.27	263.25	204.75	165.33	2.44	3.00	2.31	1.85	0.02	0.02	0.02	0.03	1.56	2.04	1.16	1.47	0.15	0.14	0.19	0.11	Ca-Na-HCO3-Cl
SW17	oxbow lake	CNB	1216.80	Mahasarakham	7224.17	8615.00	4767.50	8290.00	86.27	105.05	57.40	96.35	0.02	0.02	0.02	0.03	0.21	0.08	0.14	0.43	5.24	4.82	3.46	8.19	Na-Cl
SW22	natural(Nam Ton)	MKK	1255.70	Mahasarakham	374.50	528.25	194.00	401.25	5.48	10.19	1.87	4.39	0.02	0.03	0.02	0.02	1.60	1.66	1.35	1.78	0.37	0.55	0.24	0.31	Na-Cl
SW23	natural(Nam Ton)	MKK	1255.70	Mahasarakham	553.91	625.50	579.00	425.00	6.04	8.20	6.23	3.71	0.01	0.02	0.01	0.02	0.92	0.91	0.84	1.00	0.10	0.02	0.09	0.20	Na-Cl
SW24	natural(Nam Ton)	MKK	1255.70	Mahasarakham	234.27	264.25	237.50	190.00	2.66	3.42	2.96	1.61	0.02	0.02	0.02	0.03	0.94	1.02	0.97	0.82	0.03	0.03	0.04	0.04	Na-Cl
SW25	reservoir(KKU)	MKK	1255.70	Quaternary&Kms	994.55	1177.50	874.00	911.33	11.42	14.55	11.24	8.47	0.05	0.05	0.04	0.05	3.27	3.92	3.06	2.83	1.29	1.72	0.91	1.21	Na-Cl
SW26	reservoir(KKU)	MKK	1255.70	Quaternary&Kms	987.00	1084.25	838.00	1038.75	12.80	14.51	11.42	12.48	0.03	0.04	0.03	0.03	1.34	1.51	1.07	1.43	0.02	0.02	0.02	0.02	Ca-Na-HCO3-Cl
SW28					475.57	814.00	185.00	443.67	5.73	10.47	1.72	5.24	0.02	0.02	0.02	0.02	0.99	0.98	0.59	1.39	0.36	0.59	0.24	0.34	Ca-Na-HCO3-Cl
SW29																									Ca-Na-HCO3-Cl
SW30																									Ca-Na-HCO3-Cl
SW31																									Ca-Na-HCO3-Cl
SW32																									Ca-Na-HCO3-Cl
SW33																									Na-Cl
SW34																									Ca-K-Cl

Rainfall station (see Figure 3.1)
CBN = Chonnabot
KS = Kosum Phisai
MKK = Amphoe Muang Khon Kaen
NP = Namphong
UB = Ubonrat Dam

ANN = Annual		
SS = Summer season	March - June	
RS = Rainy season	July - October	
WS = Winter season	November - February	

Locations of the surface water samples are presented in Figure 3.6

Table 3.4 Average hydraulic and chemical compositions of groundwater at Ban Nong Khai Nun and Ban Don Bom
(averaged from 12 months : May 1989-April 1990)

mg/l

																		mg/l	parts/1000	parts/100	
WELL NO	Head	Ca	Mg	Na	K	HCO3	Cl	SO4	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	Density	TDS	Deuterium	Oxygen	Water Type
P1	152.26	103.00	10.69	102.90	3.37	363.90	162.30	3.02	6.74	0.43	0.53	49.00	0.23	0.00	0.06	0.10		562			Ca-Na-HCO3-Cl
P2	152.08	86.09	9.52	101.27	4.44	302.73	161.45	1.86	7.38	1.11	1.58	41.00	0.11	0.00	0.09	0.10		515			Ca-Na-HCO3-Cl
WW4	151.87	99.40	12.79	95.40	3.30	339.70	163.90	2.54	7.37	2.41	1.20	41.00	0.13	0.00	0.11	0.10		546			Ca-Na-HCO3-Cl
WW3	151.62	100.09	11.00	90.18	3.22	326.00	162.55	1.53	7.16	3.44	0.73	31.00	0.18	0.00	2.10	0.10		533			Ca-Na-HCO3-Cl
P3	151.46	94.18	8.45	108.36	2.96	347.91	161.00	4.02	7.00	0.17	0.40	48.00	0.03	0.00	0.03	0.10		551			Ca-Na-HCO3-Cl
P4	148.27	35.00	4.41	210.73	2.94	311.27	207.18	19.99	7.19	0.10	0.38	29.00	0.03	0.00	0.03	0.10		635			Na-HCO3-Cl
P5	143.78	71.00	8.17	348.90	6.49	152.30	605.80	13.23	7.29	0.72	28.16	8.20	0.49	0.00	0.17	0.10		1157	-59.00	-7.90	Na-HCO3-Cl
P6	151.19	87.36	7.02	76.36	3.20	329.36	100.18	1.42	7.21	0.36	0.46	50.00	0.26	0.03	0.37	0.30		404			Ca-HCO3
P7	150.04	136.82	12.21	179.64	2.39	362.82	346.27	4.84	7.27	0.45	0.33	56.00	0.10	0.00	0.63	0.10		862			Ca-Na-HCO3-Cl
P8	151.04	95.67	26.00	626.33	2.89	382.11	953.00	14.78	7.36	0.62	1.19	41.00	0.09	0.00	0.16	0.0		1907			Ca-Na-HCO3-Cl
PB5	135.73	484.00	98.36	2858.18	14.27	64.64	4623.64	1374.55	7.29	1.50	1.54	17.00	0.56	0.02	0.18	0.10		9481	-51.00	-5.70	Na-Cl-SO4
PB4	141.08	18.82	1.61	44.82	1.64	164.45	14.55	1.98	7.26	1.11	0.77	36.00	0.16	0.00	0.12	0.30		164	-46.00	-6.10	Na-HCO3
PB3	136.74	2361.43	387.71	33595.71	207.86	156.57	75871.43	3659.71	6.64	3.87	69.60							80486	-61.00	-7.70	Na-Cl-SO4
PB2	135.68	875.64	189.18	9881.82	104.91	122.00	17572.73	1697.27	6.55	2.12	9.27	1.30	0.07	17.00	0.40	0.40		32491	-48.00	-2.80	Na-Cl-SO4
WW19	137.43	22.38	13.75	264.38	22.78	126.38	382.00	64.23	7.06	0.95	2.99	0.09	0.00	15.00	0.10	0.10			-52.00		Na-Cl
PB1	134.95	419.27	176.27	9528.18	109.30	219.45	19447.27	1056.82	6.99	4.70	8.99	1.10	0.11	58.00	0.80	0.80		36000	-45.00		Na-Cl-SO4
P76	137.26	989.20	368.60	10752.00	239.10	193.90	25360.00	4739.00	[illegible]	1.22	20.13	0.62	0.01	0.68	0.10	0.30		47000			Na-Cl-SO4

Table3.5 Average hydraulic and chemical compositions of the piezometers and water wells at Ban Nong Khai Nun and Ban Don Bom
(averaged from 12 months : May 1989-April 1990)

					epm									
WELLNO	Ca	Mg	Na	K	HCO3	Cl	SO4	Mg/Ca	Ca/Na	Cl/SO4	Na/Cl	Mg/Cl	Ca/Cl	K/Cl
P1	5.14	0.88	4.48	0.09	5.96	4.58	0.06	0.17	1.15	72.71	0.98	0.19	1.12	0.02
P2	4.30	0.78	4.40	0.11	4.96	4.55	0.04	0.18	0.98	117.81	0.97	0.17	0.94	0.02
WW4	4.96	1.05	4.15	0.08	5.57	4.62	0.05	0.21	1.20	87.27	0.90	0.23	1.07	0.02
WW3	4.99	0.90	3.92	0.08	5.34	4.58	0.03	0.18	1.27	144.32	0.86	0.20	1.09	0.02
P3	4.70	0.70	4.71	0.08	5.70	4.54	0.08	0.15	1.00	54.25	1.04	0.15	1.04	0.02
P4	1.75	0.36	9.17	0.08	5.10	5.84	0.42	0.21	0.19	14.03	1.57	0.06	0.30	0.01
P5	3.54	0.67	15.18	0.17	2.50	17.08	0.28	0.19	0.23	62.00	0.89	0.04	0.21	0.01
P6	4.36	0.58	3.32	0.08	5.40	2.82	0.03	0.13	1.31	95.38	1.18	0.20	1.54	0.03
P7	6.83	1.00	7.81	0.06	5.95	9.76	0.10	0.15	0.87	96.94	0.80	0.10	0.70	0.01
P8	4.77	2.14	27.24	0.07	6.26	26.86	0.31	0.45	0.18	87.32	1.01	0.08	0.18	0.00
PB5	24.15	8.09	124.32	0.37	1.06	130.40	28.62	0.33	0.19	4.56	0.95	0.06	0.19	0.00
PB4	0.94	0.13	1.95	0.04	2.70	0.41	0.04	0.14	0.48	9.98	4.75	0.32	2.29	0.10
PB3	117.84	31.88	1461.26	5.32	2.57	2139.82	76.19	0.27	0.08	28.08	0.68	0.01	0.06	0.00
PB2	43.69	15.56	429.81	2.68	2.00	495.61	35.34	0.36	0.10	14.03	0.87	0.03	0.09	0.01
WW19	1.12	1.13	11.50	0.58	2.07	10.77	1.34	1.01	0.10	8.06	1.07	0.10	0.10	0.05
PB1	20.92	14.50	414.43	2.80	3.60	548.47	22.00	0.69	0.05	24.93	0.76	0.03	0.04	0.01
P76	49.36	30.31	467.66	6.12	3.18	715.23	98.66	0.61	0.11	7.25	0.65	0.04	0.07	0.01

Table 3.6a Aquifer Paramenter for partial penetration wells, leaky, anisotropic aquifer at Ban Nong Khai Nun

Pumping	Well	Observ.	Well	Aquifer	Aquitard			Geometric parameters of pumping and observation wells								
Well	Depth	well	Depth	type	type	r	d	l	do	lo	m	d/m	do/m	l/m	lo/m	Q(l/s))
	(m)		(m)		(m')	(m)	(m)	(m)	(m)	(m)	(m)					
WW4	131.10			Leaky	16.7		24.38	131.10			152.40	0.16		0.86		44.64
WW4	131.10	WW3	48.50	Leaky	7.6	300.00	24.38	131.10	31.90	48.50	152.40	0.16	0.21	0.86	0.32	44.64
WW4	131.10	P1	66.70	Leaky	15	275.00	24.38	131.10	8.00	70.50	152.40	0.16	0.05	0.86	0.46	44.64
WW4	131.10	P2	30.00	Leaky	10	200.00	24.38	131.10	8.00	30.00	152.40	0.16	0.05	0.86	0.20	44.64
WW4	131.10	P3	29.50	Leaky	3	170.00	24.38	131.10	8.00	29.50	152.40	0.16	0.05	0.86	0.19	44.64
WW4	131.10	P4	24.60	Leaky	3	325.00	24.38	131.10	8.00	24.60	152.40	0.16	0.05	0.86	0.16	44.64
WW4	131.10	P5	30.90	Leaky	15	530.00	24.38	131.10	8.00	30.90	152.40	0.16	0.05	0.86	0.20	44.64
WW4	131.10	P6	22.00	Leaky	3	265.00	24.38	131.10	8.00	22.00	152.40	0.16	0.05	0.86	0.14	44.64
WW4	131.10	P7	39.00	Leaky	16.5	560.00	24.38	131.10	8.00	39.00	152.40	0.16	0.05	0.86	0.26	44.64

Table 3.6b Fitted aquifer parameters for pumping well WW4 Ban Nong Khai Nun, Khon Kaen

Pumping	Well	Observ.	Well	x	r/Br	1/ur	W(p.p.)	s ave	t	Kr	S	Kz	K'	Kz/Kr	Kr/K'
Well	Depth	well	Depth					(m)	(s)	(m/s)		(m/s)	(m/s)		
	(m)		(m)												
WW4	131.10														
WW4	131.10	WW3	48.50	1.00	0.01	10.00	1.00	0.90	28800	2.59E-05	5.05E-04	6.68E-06	3.33E-11	2.58E-01	7.77E+05
WW4	131.10	P1	66.70	1.00	0.01	1.05	1.00	1.05	9600	2.22E-05	1.64E-03	6.82E-06	6.71E-11	3.07E-01	3.31E+05
WW4	131.10	P2	30.00	0.50	0.01	1.00	1.00	1.00	52200	2.33E-05	1.85E-02	3.38E-06	8.88E-11	1.45E-01	2.62E+05
WW4	131.10	P3	29.50	0.50	0.01	1.00	0.10	0.05	3480	4.66E-05	3.42E-03	9.37E-06	7.38E-11	2.01E-01	6.32E+05
WW4	131.10	P4	24.60	0.78	0.10	1.00	0.10	0.10	102000	2.33E-05	1.37E-02	3.12E-06	1.01E-09	1.34E-01	2.31E+04
WW4	131.10	P5	30.90	0.50	0.01	1.00	1.00	0.60	162000	3.89E-05	1.37E-02	8.03E-07	3.16E-11	2.07E-02	1.23E+06
WW4	131.10	P6	22.00	0.45	0.01	1.00	1.00	0.40	102000	5.83E-05	5.16E-02	3.90E-06	3.79E-11	6.70E-02	1.54E+06
WW4	131.10	P7	39.00	1.00	0.01	1.00	0.10	0.11	31200	2.12E-05	1.29E-03	1.57E-06	1.70E-11	7.41E-02	1.25E+06

Table 3.7 Assigned hydraulic conductivity values in the Ban Nong Khai Nun model

Lithologic units	Hydrogeologic units	Hydraulic conductivity (m/s)			Referrences
		Kx	Ky	Kz	
Sand, silt and clay	Ql	5.79E-06	5.79E-06	5.79E-07	Pumping tests in Huai Yai H.P.
Sandstone, siltstone and shale	Tpt	1.16E-05	1.16E-05	1.16E-07 - 1.16E-08	Pumping test at WW4
Sandstone, siltstone and shale	Kms	5.79E-06	5.79E-06	5.79E-07	Pumping tests in Huai Yai H.P.
Rock salt	rs	1.16E-08	1.16E-08	1.16E-08	Freeze and Cherry, 1979
Gypsum layer	Gp	1.16E-07	1.16E-07	1.16E-07	Freeze and Cherry, 1979

Kx and Ky are horizontal hydraulic conductivities, and Kz is a vertical hydraulic conductivity

Table 4.1 Characteristics of groundwater flow systems in Huai Yai Hydrogeolgic Province

Flow systems			Location	Area (As) (km2)	Aquifers	Porosity Sy	Piezometers and Wells	Flow direction	Flow path (Km)	Flow Depth (m)	Dhmin (m)	Kp (%)	qBmax (m/s)
Regional	Intermediate	Local											
AR1			Phu Meng Ridge (Ban Don Du)	185	Kpp	0.1	P01	W to E	20 to 40	155.00	1.63	49.80	7.32E-06
	AI1-1		Ban Khok Kwang	130	Kpp	0.15	WW1	W to E	20 to 30	80.00	0.77	23.52	4.71E-06
		AL1-1	Ban Fang	100	Qsg	0.1	F1040	W to E	0.5 to 3.0	32.00	1.53	58.43	2.25E-05
		AL1-2	Ban Muang	30	Kms	0.1	WW2	W to E	1 to 2	42.00	0.77	19.60	1.73E-06
AR2			Ban Nong Wang Hi	125	Kms	0.1	WW11	S to N	10 to 12	157.00	0.29	7.38	7.24E-07
	AI2-1		Ban Kham Pom	50	Kms	0.1	PWNZ	S to N	8 to 10	67.00	2.12	53.97	4.96E-06
AR3			Nong Lup Ridge (KKU campus)	110	Qsg	0.12	PWKS	N to S	8 to 12	166.00	0.06	2.29	1.87E-07
	AI3-1		Ban Sri Than	60	Qsg	0.13	P13	N to S	5 to 8	80.00	0.62	18.94	1.75E-06
	AI3-1		Kaeng Nam Ton	30	Kms	0.1	WW7	N to S	4 to 5	67.00	1.01	25.71	1.42E-06
		AL3-1	Ban Sa-Art	10	Kms	0.1	P20	N to S	0.5 to 2	34.00	0.88	22.40	8.12E-07
			Total area of the province =	830.00	km2					Average		28.20	4.61E-06

As = total area of the flow system (km2)

Dc = depth of flow system across
the imaginary vertical plane, Ac (m)

Dhmin = minimum water level fluctuation during 4-month period

Sy = specific yield of rocks, values of Sy are assumed according to rock types as:

Kp = groundwater coeffcient of precipitation (%)

qBmax = maximum basin flux = qB*Ar/Ac (m/s)

Qsg	Sand and gravel unit
Tpt	Phu Tok unit
Kms	Mahasarakham unit
Kpp	Phu Phan unit

Table 4.2 Average chemical compositions of rain water in Huai Yai Hydrogeologic Province

(averaged from 12 months : May 1989-April 1990)

No.	Location	Ca	Mg	Na	K	HCO3	Cl	SO4	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	emit	FEc	TDS	Deuteriu	Oxygen	Water Type
							mg/l										(gm/cc)	µS	mg/l	parts/100	parts/1000	
1	RW12	24.00	0.10	2	0.70	75.00	0	2.40	7.60	2.00	2.20					0.30		119	68			Ca-HCO3
2	RW13	4.80	1.20	1	0.50	20.00	3	0.00	6.50	3.80								38	21			Ca-HCO3
3	RW14	22.00	1.40	22	8.30	59.00	49	6.80	6.50	0.93	1.90							268	141			Ca-Na--HCO3-Cl
4	RW15	12.00	0.80	1	0.70	38.00	0	1.80	7.50	0.29	2.70							71	38			Ca-HCO3
5	RW2	16.00	0.30	1	0.70	49.00	2	4.20	8.20	0.23	1.50							95	50	-48		Ca-HCO3
6	RW3	10.00	1.20	1	0.70	20.00	6	1.80	8.70	0.22	2.60							62	38	-47		Ca-HCO3
7	RW4	7.70	1.90	2	0.50	26.00	5	1.20	7.70	0.21	2.60							53	33	-46		Ca-HCO3
8	RW5	12.00	1.10	4	0.60	46.00	2	2.70	7.70	0.23	3.30							96	48	-39		Ca-HCO3

Table 4.3 Average chemical compositions of surface water in Huai Yai Hydrogeologic Province

(averaged from 12 months : May 1989-April 1990)

No.	Location	Ca	Mg	Na	K	HCO3	Cl	SO4	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	emit	FEc	TDS	Deuteriu	Oxygen	Water Type
							mg/l										(gm/cc)	µS	mg/l	parts/100	parts/1000	
1	SW19	35.09	8.79	115	3.53	95.91	199	19.74	7.45		1.03								427.36			
2	SW20	17.06	4.25	49	11.42	103.73	71	7.44	6.79	2.69	5.62	1.2	0.37	0.00	0.00	0.4		429	215			
3	SW21	37.25	12.38	133	3.48	105.33	237	20.70	7.13	1.42	0.96	1.2	0.10	0.00	0.07	0.1		991	496			Ca-Na-HCO3-Cl
4	SW23	49.73	7.98	148	6.55	61.09	305	5.59	7.00	1.16	2.48	0	0.55	0.00	0.04	0.2		1125	554			Ca-Na-HCO3-Cl
5	SW24	18.35	4.14	64	5.33	62.45	111	2.09	7.26	0.64	0.43	8.6	0.06	0.00	0.00	0.7		519	234			Na-Cl
6	SW25	46.27	26.36	284	4.05	217.55	456	61.73	7.27	0.42	0.85	41	0.32	0.00	0.01	0.4		1888	995			Na-Cl
7	SW28	37.86	10.17	130	2.93	103.43	224	19.94	7.20	0.68	0.68	1.8	0.15	0.00	0.00	0.1		928	476			Na-Cl
8	SW31	9.10	3.00	21	13.00	28.00	32	5.40	6.80	8.20	15.00							195	112			Ca-Na-HCO3-Cl
9	SW32	58.00	7.80	159	7.50	210.00	287	3.90	7.00	2.00	3.10							1270	629			Ca-Na-HCO3-Cl
10	SW33	33.00	4.40	166	7.50	92.00	256	43.00	6.20	0.88	0.00							1060	556			Ca-Na-HCO3-Cl
11	SW34	23.00	11.00	103	11.00	62.00	197	60.00	7.00	0.64	1.40							811	436			Na-Cl

Table4.4 Average chemical compositions of dug wells in Huai Yai Hydrogeologic Province

(averaged from 12 months : May 1989-April 1990)

No.	Location	Ca	Mg	Na	K	HCO3	Cl	SO4	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	emit	FEc	TDS	Deuteriu	Oxygen	Water Type
							mg/l										(gm/cc)	µS		parts/100	parts/1000	
1	DG1	7.20	0.90	13	2.60	22.00	3	4.20	7.50	0.58	1.50							138	66	-49		Ca-Na-HCO3
2	DG11	42.00	4.80	116	13.00	59.00	95	24.00	6.00	0.35	37.00							902	441			Na-Cl
3	DG13	27.00	2.10	8	2.60	87.00	12	1.80	6.20	4.70	0.70							194	97			Ca-HCO3
4	DG14	24.00	4.30	29	6.40	88.00	52	9.30	6.70	11.00	1.50							323	170			Ca-Na-HCO3-Cl

Table 4.5 Average hydraulic heads and chemical compositions of groundwater in Huai Yai Hydrogeologic Province (averaged from 12 months : May 1989-April 1990)

No.	WELL NO	Head	Ca	Mg	Na	K	HCO3	Cl	SO4	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	Density	FEc	TDS	euteriu	Oxygen	Water Type
		(m)						mg/l										(gm/cc)	µS	mg/l	parts/100	parts/1000	
1	F626	214.66	269.83	62.33	159	17.67	457.08	366	88.08	7.08	3.11	369.92	37	0.57	0.00	0.98	0.1		2660	1596			Ca-Cl
2	F459		672.83	108.00	292	4.98	388.67	1571	28.75	6.69	7.30	201.83					0.20		5612	3248			Ca-Cl
3	F531	165.92	370.55	90.73	171	45.64	379.09	598	147.36	6.89	8.49	512.09	50	0.42	0.00	1.20	0.1	1.0003	3310	2123	-47		Ca-Cl
4	F624	193.20	1275.00	94.67	846	8.43	9.28	2997	1143.25	7.08	32.98	5.96	3.6	1.10	0.04	23.00	0.1		10058	6544			Ca-Cl
5	P01	202.45	64.83	8.39	23	1.66	251.33	32	4.62	6.92	1.75	1.54	16	0.34	0.07	0.34	0.1		495	257			Ca-HCO3
6	F639	197.03	141.25	24.00	62	0.89	548.25	83	29.70	6.95	1.23	0.47	45	0.70	0.00	0.04	0.2		1019	611			Ca-HCO3
7	F641	184.11	181.33	22.50	106	2.26	386.67	323	7.56	7.05	5.53	1.28	36	0.12	0.00	0.37	0.1		1631	856			Ca-HCO3
8	P12	182.33	35.25	18.92	11	5.23	219.75	8	5.43	6.65	1.19	2.79	50	0.06	0.02	0.11	0.3		365	192			Ca-HCO3
9	PWNZ	168.52	135.00	33.86	96	3.83	672.83	102	2.02	7.00	2.77	0.48					0.20		1256	710	-36		Ca-HCO3
10	F642	194.96	127.64	29.73	67	1.63	491.36	128	8.88	7.19	2.73	11.48	37	0.13	0.00	0.55	0.1		1170	615			Ca-HCO3
11	WW1	194.62	32.27	4.95	18	5.78	148.82	17	2.00	7.33	24.20	9.84	1	0.43	0	0.17	0.1	1.0008	336	538	-53	-6.60	Ca-HCO3
12	P13	179.63	41.27	15.09	35	1.76	205.18	55	17.97	6.75	0.39	0.38	29	0.10	0.03	6.50	0.4	1.0008	455	273	-56		Ca-HCO3
13	P14		13.51	3.76	11	2.10	56.80	18	8.05	6.13	0.52	3.19	36	0.05	0.02	0.34	0.1	1.0010	206	90	-37	-3.82	Ca-HCO3
14	PWKS	182.05	40.43	35.71	25	3.10	203.57	32	67.14	7.19	0.16	36.57	60	0.00	0.00	0.09	0.2	1.0015	586	338			Ca-HCO3
15	PWTW	163.14	163.14	95.14	17	4.91	385.29	24	466.57	7.23	1.18	4.77	40	0.02	0.03	0.59	0.3	1.0015	1943	963	-59		Ca-HCO3-SO4
16	F672		257.00	52.92	132	4.38	482.58	387	26.17	7.40	0.07	200.83	62	0.18	0.00	0.82	0.1		2305	1300			Ca-HCO3-Cl
17	U836	174.57	310.60	49.70	135	0.83	366.10	358	93.30	7.04	1.45	441.90	46	0.22	0.00	0.42	0.2		2600	162			Ca-HCO3-Cl
18	F716	154.54	394.92	87.83	315	3.26	362.50	1207	5.90	7.08	1.73	45.83	34	0.52	0.00	7.70	0.1		4180	2238			Ca-Na-Cl
19	F186		158.00	45.72	111	2.00	129.55	240	389.00	6.47	1.28	21.64							1610	986			Ca-Na-Cl
20	F564	148.24	64.75	11.46	93	1.34	446.83	32	1.43	7.46	5.55	0.63	60	0.11	0.02	0.34	0.1		766	423			Ca-Na-HCO3
21	P32	172.56	90.30	22.60	118	2.48	580.60	76	2.46	7.25	0.87	0.80	40	0.30	0.02	0.16	0.1	1.0012	1090	599			Ca-Na-HCO3
22	WW11	168.21	86.00	20.29	106	1.53	577.86	39	0.60	7.14	0.33	0.55	49	0.03	0.02	4.90	0.1	1.0014	986	836	-57	-5.78	Ca-Na-HCO3
23	WW19	137.43	22.38	13.75	264	22.78	126.38	382	64.23	7.64	0.95	2.99					0.10		1583	360			Ca-Na-HCO3
24	WW2	173.40	45.67	5.77	88	2.25	295.00	70	2.58	7.05	7.30	1.20						1.0010	920	1367	-54	-9.64	Ca-Na-HCO3
25	P23	194.11	50.75	5.58	94	11.40	302.30	22	44.50	7.33	14.72						0.10		675	424			Ca-Na-HCO3
26	F1040	184.26	17.75	6.68	22	1.97	93.75	28	5.53	6.15	13.57	0.56							255	134			Ca-Na-HCO3-Cl
27	P22	172.26	109.45	20.24	142	1.65	408.73	173	4.85	6.75	0.08	91.45	49	0.07	0.00	0.19	0.1	1.0010	1373	736			Ca-Na-HCO3-Cl
28	P11	181.73	50.00	37.86	49	2.92	273.67	73	63.28	6.85	1.86	7.08	36	0.22	0.09	0.81	0.4	1.0015	857	417	-50		Ca-Na-HCO3-Cl
29	F861	188.95	81.67	12.34	210	1.77	303.58	57	393.92	7.67	2.78	0.40	27	0.17	0.00	2.10	0.1		1403	909			Na-Cl
30	F480		238.00	49.73	641	7.83	357.27	1303	33.91	7.22	0.21	42.27							4761	2493			Na-Cl
31	F606	157.55	154.29	53.43	998	7.66	696.00	1327	293.71	7.19	30.02	100.43	68	0.50	0.01	0.05	0.8	1.0041	4914	3267	-35		Na-Cl
32	F859	154.78	129.42	23.58	630	2.29	265.33	1103	33.75	7.33	4.89	0.99	34	0.20	0.00	3.50	0.1	1.0026	3692	2085	-59	-6.49	Na-Cl
33	L794	170.00	346.00	177.92	2003	2.17	523.08	3643	295.67	7.24	12.89	1.57	62	0.53	0.01	15.00	0.2		11683	6723			Na-Cl
34	P17	153.20	90.82	38.05	2215	9.08	129.64	3574	25.18	7.32	0.64	2.38	10	0.14	0.04	0.17	0.2	1.0054	10300	6009	-46		Na-Cl
35	P18	153.15	46.00	11.04	780	3.29	308.82	1102	15.51	7.02	1.06	1.38	17	0.20	0.02	1.00	0.2	1.0023	3463	2110	-44		Na-Cl
36	P19	154.03	17.09	2.81	262	1.87	304.82	270	0.90	7.38	0.95	0.66	9.4	0.22	0.00	0.98	0.3	1.0012	1345	707	-45		Na-Cl
37	P34	165.40	561.27	256.18	2220	105.91	360.64	4736	22.13		2.56	3.26	8.4	0.05	0.00	0.12	0.1		13900	7986			Na-Cl
38	P68	169.00	1056.27	331.91	21595	227.09	195.36	43645	2171.82	7.00	2.95	55.89	48	0.56	0.46	2.30	0.4		99191	75618			Na-Cl
39	P70	176.80	1168.33	484.17	9375	234.50	238.25	18433	250.00	7.08	1.89	8.90	18	0.96	0.12	0.69	0.2	1.0012	19900	30833			Na-Cl
40	P73	154.04	41.10	31.42	1674	12.97	465.30	2421	119.70	6.65	1.70	2.76	10	0.13	0.05	0.24	0.2	1.0046	7450	4532	-51	-6.06	Na-Cl
41	P73A	155.09	69.20	32.80	968	17.00	540.00	1107	410.40	7.12	0.90	111.40	57	0.07	0.03	0.35	0.2		4120	2984	-57		Na-Cl
42	P75	148.36	1070.60	166.70	352	15.80	119.20	2899	2.25	6.85	8.21	7.95	1.4	9.80	0.02	0.18	0.1	1.0059	6680	4572	-59		Na-Cl
43	WW7	156.48	23.36	4.82	519	2.33	220.10	706	1.74	7.48	4.72	0.68	8	0.14	0.00	0.06	0.1	1.0016	2418	1581	-47	-6.88	Na-Cl
44	F488		9.81	6.74	8	2.22	72.92	8	4.20	6.32	19.30	0.46							138	74			Na-Cl
45	P15	158.84	529.45	176.55	6981	69.10	313.40	25164	823.45	6.79	8.13	83.37	40	0.13	0.00	0.30	0.1	1.0343	19900	43336	-37		Na-Cl
46	P16	159.62	177.20	50.60	456	3.80	352.20	944	220.30	6.94	0.99	5.84	50	0.26	0.07	0.09	0.5	1.0025	3780	2196	-58		Na-Cl
47	P76	146.11	989.20	368.60	10752	239.10	193.90	25360	4739.00	6.87	1.22	20.13	17	0.49	0.08	0.17	0.3		66870	48580			Na-Cl
48	P81	142.79	419.27	176.27	9528	109.30	219.45	19447	1056.82	6.96	4.70	8.99	0	1.10	0.11	58.00	0.8		51209	34000			Na-Cl-SO4
49	P82	144.32	875.64	189.18	9882	104.91	122.00	17573	1697.27	6.89	2.12	9.27	0.4	1.30	0.07	17.00	0.4		47573	32491			Na-Cl-SO4
50	P83	144.84	2361.43	387.71	33596	207.86	156.57	75871	3659.71	6.69	3.87	69.60							14807	80486			Na-Cl-SO4
51	P85	151.77	484.00	98.36	2858	14.27	64.64	4624	1374.55	6.88	1.50	1.54	17	0.56	0.02	0.18	0.1		15045	9481			Na-Cl-SO4
52	F401	152.50	22.50	3.61	117	0.94	360.90	25	0.80	7.20	0.14	0.88	37	0.00	0.01	0.01	0.2		618	347			Na-HCO3
53	P31	168.69	21.20	6.02	186	3.36	525.40	38	1.00	7.40	1.01	1.04	30	0.15	0.01	0.16	0.2		900	518	-56		Na-HCO3
54	P20	153.62	12.79	2.33	217	1.10	290.45	196	1.19	7.39	0.89	0.95						1.0011	1101	572	-49		Na-HCO3-Cl

Table 4.6 Sequences of hydrochemical facies development for groundwater flow systems in Huai Yai Hydrogeologic Province

Regional System	Intermediate system	Local system	Areal area (km^2)	Hydrochemical Facies along flow paths
1. Phu Meng (AR1)			185	Ca-HCO_3→Ca-Cl→Ca-Na-Cl →Na-Cl
	Ban Khok Kwang (AI1-1)		130	Ca-HCO_3 →Ca-Na-HCO_3-Cl → Na-Cl
		Ban Fang (AL1-1)	32	Ca-HCO_3 → Ca-Na-HCO_3-Cl
		Ban Muang (AL1-2)	42	Ca-Na-HCO_3
2. Nong Wang Hi (AR2)			125	Ca-HCO_3→Na-Cl
	Ban Kham Pom (AI2-1)		50	Ca-HCO_3 →Na-Cl
3. Nong Lup (AR3)			110	Ca-HCO_3 → Ca-Na-SO_4-Cl → Na-Cl
	Ban Sri Than (AI3-1)		160	Ca-HCO_3 →Ca-Na-SO_4-Cl → Na-Cl
		Ban Sa Art (AL3-1)	18	Na-HCO_3 →Na-Cl

Table 4.7a Average chemical compositions of rain water for Phu Meng (AR1) and NongLup (AR2) regional flow systems in Huai Yai Hydrogeologic Province

(averaged from 12 months : May 1989-April 1990)

	Flow				epm				mg/l									(gm/cc)	parts/1000	parts/10
WELL	system	Ca	Mg	Na	K	HCO3	Cl	SO4	TDS	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	Density	Deuterium	Oxygen
RW13	AR1	0.24	0.10	0	0.01	0.33	0.09	0.00	21	6.50	3.80									
RW12	AR3	1.20	0.01	0	0.02	1.23	0.00	0.05	68	7.60	2.00	2.2					0.3			

Table 4.7b Average chemical compositions and hydraulic heads for Phu Meng (AR1) and NongLup (AR2) regional flow systems in Huai Yai Hydrogeologic Province

(averaged from 12 months : May 1989-April 1990)

	Flow	mg/l				epm						mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	(gm/cc)	parts/1000	parts/10
Well No	system	TDS	Cl	Ca	Mg	Na	K	HCO3	SO4	HEAD(m)	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	Density	Deuterium	Oxygen
P01	AR1	257	0.90	3.24	0.69	1.01	0.04	4.12	0.10	202.45	6.92	1.75	1.54	16	0.34	0.07	0.34	0.1			
F639	AR1	611	2.34	7.05	1.97	2.69	0.02	8.98	0.62	197.03	6.95	1.23	0.47	45	0.70	0.00	0.04	0.2			
F459	AR1	3248	44.30	33.57	8.88	12.71	0.13	6.37	0.60	160.00	6.69	7.30	201.83					0.20			
F716	AR1	3820	63.74	38.62	12.99	15.88	0.06	6.80	0.08	154.54	7.08	1.73	45.83	34	0.52	0.00	7.70	0.1			
P12	AR3	192	0.23	1.76	1.56	0.46	0.13	3.60	0.11	182.33	6.65	1.19	2.79	50	0.06	0.02	0.11	0.3			
PWKS	AR3	338	0.90	2.02	2.94	1.07	0.08	3.34	1.40	182.05	7.19	0.16	36.57	60	0.00	0.00	0.09	0.2	1.0015		
P17	AR3	6009	100.79	4.53	3.13	96.36	0.23	2.12	0.52	153.20	7.32	0.64	2.38	10	0.14	0.04	0.17	0.2	1.0054	-46	
P18	AR3	2110	31	2.30	0.91	34	0.08	5.06	0.32	153.15	7.02	1.06	1.38	17	0.20	0.02	1.00	0.2	1.0023	-44	

Table 4.7c Ionic ratios for Phu Meng (AR1) and Nong up (AR3) regional flow systems in Huai Yai Hydrogeologic Province

(averaged from 12 months : May 1989-April 1990)

Well No	Flow system	HCO3+SO4	Mg/Ca	SO4/HCO3	HCO3/Cl	Ca/Mg	Ca/Na	Ca/K	Ca/(HCO3+SO4)	Cl/Ca	Cl/Na	Cl/K	Cl/SO4	Na+K	Na/Cl	Na-Cl	Ca+Mg	Ca/SO4	Mg/SO4	Ca+Mg/SO4
P01	AR1	4.22	0.21	0.02	4.60	4.69	3.20	76.28	0.77	0.28	0.89	21.11	9.31	1.05	1.13	0.12	3.93	33.62	7.17	40.79
F639	AR1	9.60	0.28	0.07	3.84	3.57	2.62	309.08	0.73	0.33	0.87	102.54	3.78	2.71	1.15	0.35	9.02	11.40	3.19	14.59
F459	AR1	6.97	0.26	0.09	0.14	3.78	2.64	263.43	4.82	1.32	3.49	347.60	74.02	12.84	0.29	-31.59	42.46	56.09	14.84	70.93
F716	AR1	6.88	0.34	0.01	0.11	2.97	2.43	686.43	5.61	1.65	4.01	1132.82	785.02	15.93	0.25	-47.86	51.62	475.68	160.03	635.71
P12	AR3	3.71	0.88	0.03	15.42	1.13	3.84	13.14	0.47	0.13	0.51	1.75	2.07	0.59	1.96	0.22	3.31	15.56	13.76	29.33
PWKS	AR3	4.73	1.46	0.42	3.70	0.69	1.88	25.45	0.43	0.45	0.84	11.38	0.65	1.15	1.19	0.17	4.95	1.44	2.10	3.54
P17	AR3	2.65	0.69	0.25	0.02	1.45	0.05	19.51	1.71	22.24	1.05	433.92	192.25	96.59	0.96	-4.43	7.66	8.64	5.97	14.61
P18	AR3	5.38	0.40	0.06	0.16	2.53	0.07	27.27	0.43	13.54	0.92	369.36	96.28	34.02	1.09	2.85	3.20	7.11	2.81	9.92

Table 4.6 Saturation indices of groundwater with respect to dolomite, calcite, gypsum, anhydrite and halite for Phu Meng (AR1) and Nong Lup (AR3) regional flow systems in Huai Yai Hydrogeologic Province

Well No.	Flow systems	Aquifers	Minerals	Saturation Index					T	Ionic strength
				SId	SIc	SIg	SIa	SIh	degree C	
P01	AR1	Shale (Kkk)	d +c + a +g	-1.81	-0.61	-2.62	-2.78	-7.71	30.00	0.0060
F639	AR1	Shale (Kkk)	d +c + a +g	-0.46	0.00	-1.68	-1.84	-6.90	30.00	0.0133
F459	AR1	Shale & siltstone (Kms)	d +c + a + g +	-0.18	0.00	-1.47	-1.63	-5.05	30.00	0.0717
F716	AR1	Shale & siltstone (Kms)	d +c + a + g +	-0.32	0.00	-2.38	-2.54	-4.80	30.00	0.0875
P12	AR3	Sand and gravel (Qsg)	d + c	-2.47	-1.25	-2.80	-2.96	-8.63	30.00	0.0044
PWKS	AR3	Sand and gravel (Qsg)	d + c	-0.98	-0.61	-2.71	-2.87	-7.69	30.00	0.0078
P17	AR3	Shale & siltstone (Kms)	d +c + a + g +	-1.33	-0.63	-2.36	-2.52	-3.84	30.00	0.1708
P18	AR3	Shale & siltstone (Kms)	d +c + a + g +	-1.57	-0.52	-2.36	-2.52	-4.73	30.00	0.0386

d = dolomite; c = calcite; g = gypsum; a = anhydrite; h = halite

Table 4.9 Results of model calibration and sensitivity analysis for groundwater heads in Huai Yai Hydrogeologic Province

			m amsl				32 Layers			27 Layers					27 Layers			Model Head in metres above mean sea level					
No	Row	Column	M. elev	M. L.	Well #	Mean head	refHY50.xyz	refA-1.xyz	refA-2.xyz	refA-3.xyz	refA-4.xyz	refA-5.xyz	refA-6.xyz	refA-7.xyz	refA-8.xyz	refA-9.xyz	refA-91.xyz	refA-10.xyz	refA-11.xyz	refA-12.xyz	refA-13.xyz	refA-14.xyz	refA-D.xyz
1	12	16	130	6	P70	176.80	177.03	177.02	177.02	177.02	177.03	177.00	177.00	177.04	177.28	178.22	177.45	158.18	153.41	177.46	177.16	177.02	177.01
2	14	19	130	6	WW2	173.40	177.69	177.62	176.80	176.80	177.78	178.00	177.96	177.70	176.64	174.79	176.79	155.88	151.56	176.13	177.07	177.8	177.91
3	22	28	90	8	P19	154.02	155.64	155.76	155.13	155.13	155.87	156.00	155.98	155.81	154.92	152.99	153.77	126.6	119.99	154.44	155.3	155.81	153.99
4	22	28	50	10	WW7	153.86	155.46	155.68	154.87	154.87	155.82	156.00	155.97	155.74	154.61	152.48	153.21	111.22	99.13	154.06	155.08	155.73	153.76
5	31	21	110	7	P31	172.56	173.89	173.92	173.42	173.42	173.99	174.00	174.00	173.98	173.73	171.57	172.92	145.79	135.95	173.38	173.89	173.91	172.96
6	31	19	110	7	P32	168.69	173.50	173.56	172.35	172.35	173.78	174.00	173.96	173.69	172.65	171.03	172.2	146.37	136.4	172.21	173.05	173.66	171.94
7	31	19	90	8	WW11	168.21	173.33	173.48	172.09	172.09	173.74	174.00	173.96	173.64	172.47	170.87	171.82	139.11	125.85	172.01	172.9	173.59	171.93
8	25	21	130	6	F859	154.64	155.01	155.01	155.09	155.09	155.01	155.00	155.00	155.01	155.06	155.17	155.3	146.8	144.33	155.1	155.04	155.01	155
9	24	21	130	6	P73A	153.80	153.04	153.06	153.24	153.24	153.02	153.00	153.00	153.03	153.17	153.5	153.63	145.61	143.83	153.25	153.11	153.03	153.01
10	24	21	90	8	P73	154.00	153.21	153.16	153.65	153.65	153.07	153.00	153.01	153.10	153.44	154.08	154.47	129.48	122.87	153.64	153.29	153.09	153.03
11	22	28	90	8	P19	154.02	155.64	155.76	155.13	155.13	155.87	156.00	155.98	155.81	154.92	152.99	153.77	126.6	119.99	154.44	155.3	155.81	153.99
12	22	28	50	10	WW7	153.86	155.46	155.68	154.87	154.87	155.82	156.00	155.97	155.74	154.61	152.48	153.21	111.22	99.13	154.06	155.08	155.73	153.76
13	22	28	130	6	F401	152.50	155.86	155.86	155.49	155.49	155.92	156.00	155.99	155.89	155.34	153.87	154.95	142.39	140.9	155.01	155.58	155.9	154
14	20	30	110	7	P18	152.67	153.92	153.94	153.86	153.86	153.96	154.00	153.99	153.94	153.72	153.14	153.22	136.88	131.24	153.59	153.82	153.95	153
15	18	31	130	6	P16	159.62	157.01	157.01	157.11	157.11	157.00	157.00	157.00	156.99	156.96	156.81	156.84	148.8	144.47	156.94	156.98	157.01	157
16	18	31	70	9	P15	159.32	157.04	157.03	157.37	157.37	156.99	157.00	157.00	156.98	156.90	156.54	156.62	127.57	113.15	156.83	156.94	157.02	157.15
17	14	32	130	6	PWKS	182.05	183.88	183.86	183.02	183.02	183.97	184.00	183.99	183.95	183.60	181.38	183.37	160.51	152.33	183.25	183.79	183.89	183.95
18	14	32	90	8	PWT	178.45	183.79	183.81	182.63	182.63	183.95	184.00	183.99	183.93	183.44	180.36	182.19	145.91	130.62	182.94	183.71	183.83	183.92
19	15	29	130	6	F186	180.15	175.06	175.05	175.11	175.11	175.05	175.00	175.01	175.07	175.22	174.73	174.83	156.63	150.66	175.22	175.18	175.03	175.02
20	25	35	90	8	P76	146.11	144.07	144.06	144.17	144.17	144.03	144.00	144.01	144.05	144.17	144.3	144.52	121.26	116.62	144.23	144.12	144.03	144.01
21	29	27	130	6	F672	153.67	154.97	154.96	154.82	154.82	154.98	155.00	155.00	154.97	154.91	155.04	155.18	145.83	143.19	154.92	154.92	154.98	154.99
22	36	23	130	6	F564	150.01	152.03	152.03	152.07	152.07	152.02	152.00	152.00	152.03	152.17	152.61	152.62	147.05	143.93	152.26	152.11	152.03	152.01
23	31	16	130	6	P34	165.50	168.02	162.98	162.99	162.99	162.99	163.00	163.00	162.99	162.99	163.37	163.25	150.58	147	163.04	162.97	163	163
		Mean error (ME)					-1.16	-0.97	-0.63	-0.63	-1.03	-1.09	-1.08	-1.01	-0.65	0.24	-0.36	21.38	28.32	-0.46	-0.80	-1.00	-0.02
		Mean absolute error (MAE)					2.34	2.38	1.92	1.92	2.45	2.53	2.51	2.42	2.01	1.65	1.80	21.38	28.32	1.79	2.19	2.41	2.15
		Root mean squared rror (RMS)					2.80	2.83	2.34	2.34	2.92	3.00	2.99	2.88	2.46	1.99	2.29	23.82	31.65	2.28	2.63	2.87	3.45

Results of simulation of 32 model layers

refHY-50.xyz for Kx=Ky and Kz =1E-2 m/d

Results of simulation of 27 model layers

refA-1.xyz for Kx-Ky and Kz = 3.0E-1 m/d or Vcont =1.5E-2

Results of simulation of 27 model layers

and variaton of horizontal anisotropy (Kx or Ky)

refA-2.xyz for Kx= 10x Ky and Kz =3.0E-1 m/d or Vcont=1.5E-2

refA-3.xyz for Kx= 5x Ky and Kz =3.0E-1 m/d or Vcont=1.5E-2

Results of simulation of 27 model layers and variaton in Kz

refA-5.xyz : for Kx=Ky and Kz = 2E+1 m/d or Vcont =1.0

refA-6.xyz : for Kx= Ky and Kz = 2.0 E+0 m/d or Vcont= 1.0E-1

refA-7.xyz : for Kx= Ky and Kz = 4.0E-1 m/d or Vcont= 1.0E-2

refA-8.xyz : for Kx= Ky and Kz = 2.0E-2 m/d or Vcont= 1.0E-3

refA-9.xyz : for Kx= Ky and Kz = 2.0E-3 m/d or Vcont= 1.0E-4

refA-10.xyz : for Kx= Ky and Kz = 2.0E-4 m/d or Vcont= 1.0E-5

refA-11.xyz : for Kx= Ky and Kz = 2.0E-5 m/d or Vcont= 1.0E-6

Results of simulation of 27 model layers

and doulble and half of Kx and Ky values

refA-12.xyz = double Kx and Ky values (the rest para. = refA-8.xyz)

refA-12.xyz = half Kx and Ky values (the rest para. = refA-8.xyz)

Results of simulation of 27 model layers and

homogenous case , Kx=Ky=Kz=1 m/d

refA-14.xyz =   for Kx=Ky=0.5 m/d and Kz = 0.4 or Vcont= 1.0E-2

Table 4.10 Hydrogeologic parameters of flow systems determined by mapping or piezometric analysis and 3-D models for Huai Yai Hydrogeologic Province

	Piezometric analysis			A steady state 3-D Model		
Hydraulic parameters	Phu Meng R.F.S. AR1	Nong Wang Hi R.F.S. AR2	Nong Lup R.F.S. AR3	Phu Meng R.F.S. AR1	Nong Wang Hi R.F.S. AR2	Nong Lup R.F.S. AR3
Flow path (Km)	20 - 40	20 -30	8 - 12	?	?	?
Flow depth (m)	155	157	166	< 140	<160	<190
Flux (m/s) Vx	7.32E-06	7.24E-07	1.87E-0-7	3.00E-11 - 2.75E-07 (4.86E-08)	2.3E-11 - 2.60E-07 (4.74E-08)	2.31E-10 - 1.13E-07 (3.59E-08)
Vy				1.16E-12 - 3.25E-07 (4.28E-08)	1.16E-11 - 3.16E-07 (4.05E-08)	1.50E-09 - 1.13E-07 (4.28E-08)
Vz				8.1E-12 - 2.43E-08 (3.82E-09)	5.79E-12 - 2.31E-08 (2.67E-09)	1.04E-11 - 1.45E-08 (1.71E-09)
Flow direction	W → E	S → N	N → S	W → E	S → N	N → S
Recharge rate (m/s)	1.86E-08	2.76E-09	8.56E-10	> 0.00 - 4.63E-09	> 0.00 - 9.26E-09	> 0.00 - 4.63E-09
GW. Coef. of precipitation (%)	49.80	53.97	2.29	> 0.00 - 1.53E-07	> 0.00 - 3.17E-07	> 0.00 -1.53E-07

Numbers in brackets are averaged from the value ranges in an individual flow system.

Table 5.1 Average chemical compositions of rain water in Chonnabot Hydrogeologic Province

				epm					mg/l	
Location	Ca	Mg	Na	K	HCO3	Cl	SO4	LPH	TDS	WATER TYPE
RW7	1.35	0.07	0.07	0.04	1.41	0.00	0.05	7.10	79.00	Ca-HCO3

Table5.2 Average chemical compositions of surface water in Chonnabot Hydrogeologic Province
(averaged from 12 months : May 1989-April 1990)

							mg/l										(gm/cc)		mg/l	parts/1000	parts/1000	
No.	Well No	Ca	Mg	Na	K	HCO3	Cl	SO4	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	Density	FEc	TDS	Deuterium	Oxygen	Water Type
1	SW15	36.91	9.67	115.18	3.68	97.64	208.46	17.23	7.44	1.55	1.00	1	0.69	0.00	0.00	0.1		864	444			Na-Cl
2	SW18	38.17	9.83	134.25	3.49	103.33	234.13	20.29	7.19	1.45	1.34	1.4	0.32	0.00	0.00	0.1		908	474			Ca-K-Cl

Table 5.3 Average hydraulic heads and chemical compositions of groundwater in Chonnabot Hydrogeologic Province
(averaged from 12 months : May 1989-April 1990)

No	WELL No	Ca	Mg	Na	K	HCO3	Cl mg/l	SO4	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	Density (gm/cc)	FEc µS	TDS mg/l	Deuterium parts/1000	Oxygen parts/1000	Water Type
1	WW13	82.40	17.60	58.20	2.20	483.80	10.74	2.25	6.90	0.07	0.53	49	0.03	0.02	6.10	0.3		680	412	-38		Ca-HCO3
2	P49	339.75	395.75	356.00	4.38	580.25	461.88	2163.25	7.21	3.29	3.23							4663	3973			Ca-Mg-Cl-SO4
3	P45	61.55	7.10	111.45	3.23	267.55	34.36	156.91	7.19	2.46	1.30	20	0.71	0.00	0.20	0.6		845	513			Ca-Na-HCO3-SO4
4	P50	195.60	50.30	529.80	28.90	556.50	783.70	166.40	7.22	1.47	151.78	108	0.12	0.03	0.19	0.5		3540	2156	-53		Na-Cl
5	L798	66.83	32.42	65.08	0.76	211.58	29.92	211.67	6.99	28.89	1.20	68	0.13	0.00	0.14	0.3		917	511			Na-Cl
6	S832	85.58	21.08	486.67	4.07	476.08	688.08	12.05	7.23	0.98	0.48	0.6	0.01	0.00	0.63	0.1		2775	1544			Na-Cl
7	P48	527.00	410.10	691.40	8.42	315.10	725.80	3232.00	7.10	3.07	2.43	18	0.23	0.00	0.13	0.5		5590	5807			Na-Cl-SO4
8	L791	129.83	101.17	1166.08	338.42	322.30	#######	411.00	7.12	1.32	580.83	54	0.08	0.02	3.60	0.6		7042	4674			Na-Cl-SO4
9	P77	1182	1005	13033	582	169	26530	719	6.97	1.17	71.62	10	108	0.11	3.2	0.2		19900	44300			

Table 5.4 Average chemical compositions of groundwater for a regional groundwater flow system in Chonnabot Hydrogeologic Province
Huai Hin Kaeng (BR1) regional flow system (averaged from 12 months: may 1989- April 1990)

					epm					mg/l	mg/l	mg/l	mg/l	mg/l				(gm/cc)		parts/1000	parts/1000	
Well No	Flow system	TDS	Cl	Ca	Mg	Na	K	HCO3	SO4	HEAD(	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	Density	Deuterium	Oxygen	Water Type
WW13	BR1	412	0.30	4.11	1.45	2.53	0.06	7.93	0.05	196.54	6.90	0.07	0.53	49.00	0.03	0.02	6.10	0.30		-38.00		Ca-HCO3
P50	BR1	2156	22.09	9.76	4.14	23.04	0.74	9.12	3.46	158.87	7.22	1.47	151.78	108.00	0.12	0.03	0.19	0.30		-53.00		Na-Cl
P77	BR1	44300	747.85	58.98	82.65	966.89	14.88	2.77	14.97	151.63	6.97	1.71	71.62	10.00	1.80	0.11	3.20	0.20		-56.00		Na-Cl

Table 5.5 Ionic ratios for selected a regional groundwater flow system in Chonnabot Hydrogeologic Province (ionic ratios calculated in meq/l)
Huai Hin Kaeng (BR1) regional flow system (ionic ratios calculated in meq/l)

Well No.	Flow system	HCO3+SO4	Mg/Ca	SO4/HCO3	HCO3/Cl	Ca/Mg	Ca/Na	Ca/K	Ca/(HCO3+SO4)	Cl/Ca	Cl/Na	Cl/K	Cl/SO4	Na+K	Na/Cl	Ca+Mg	Ca/SO4	Mg/SO4	Ca+Mg/SO4
WW13	BR1	7.98	0.35	0.01	26.19	2.84	1.62	73.08	0.52	0.07	0.12	5.38	6.46	2.59	8.36	5.56	87.78	30.90	118.68
P50	BR1	12.58	0.42	0.38	0.41	2.36	0.42	13.21	0.78	2.26	0.96	29.89	6.38	23.78	1.04	13.90	2.82	1.19	4.01
P77	BR1	17.74	1.40	5.40	0.004	0.71	0.10	3.96	3.33	12.68	1.32	50.24	49.96	581.77	0.76	141.63	3.94	5.52	9.46

Table 5.6 Characteristics of groundwater flow systems in Chonnabot Hydrogeologic Province

Flow systems			Location	Area (As) (km2)	Aquifers	Porosity Sy	Piezometers and Wells	Flow direction	Flow path (Km)	Flow Depth (m)	Dhmin (m)	Kp (%)	qBmax (m/s)
Regional	Intermediate	Local											
BR1			Ban Huai Hin Keang	146.00	Qsg Kkk Kpp	0.10	WW13	N, E, S, W	8 to 10	170.00	0.13	3.39	4.82E-07
		BL1-1	Ban Nong Ben	30.00	Kms	0.10	P49	N, E, S, W	0.5 to 2	40.00	0.51	13.30	2.51E-06
		Total area of the province =		176.00	km2					Average		8.35	1.50E-06

As = total area of the flow system (km2)
Dc = depth of flow system across
the imaginary vertical plane, Ac (m)
Dhmin = minimum water level fluctuation during 4-month period
Sy = specific yield of rocks, values of Sy are assumed according to rock types as:
Sy of Qsg = 0.15: Jsk, Jpw and Kkk = 0.1, Kpp = 0.12, and Kms = 0.1
Kp = groundwater coeffcient of precipitation (%)

qBmax = maximum basin flux = qB*Ar/Ac (m/s)

Qsg	Sand and gravel unit
Kms	Mahasarakham unit
Kkk	Khok Kruat unit
Kpp	Phu Phan unit

Table 5.7 Sequences of hydrochemical facies development for groundwater flow systems in Chonnabot Hydrogeologic Province

Regional system	Intermediate system	Local system	Areal area (km^2)	Hydrochemical facies along flow paths
Huai Hin Keang (BR1)			104	$Ca\text{-}HCO_3 \rightarrow Na\text{-}Cl \rightarrow Na\text{-}SO_4\text{-}Cl$
		Ban Nong Ben (BL1-1)	28	$Ca\text{-}Na\text{-}HCO_3$

Table 5.8 Saturation indeces of groundwater with respect to dolomite, calcite, gypsum, anhydrite and halite Huai Hin Keang (BR1) regional flow systems in Chonnabot Hydrogeologic Province

Well No.	Flow system	Aquifers	Minerals	Saturation Index					T	Ionic
				SId	SIc	SIg	SIa	SIh	degree C	strength
WW13	BR1	Shale	d +c + a +g	-0.93	-0.28	-2.89	-3.05	-7.80	30.00	0.0085
		(Kkk)								
P50	BR1	Shale & siltstone	d +c + a + g + h	-0.12	0.00	-1.14	-1.31	-5.05	30.00	0.0370
		(Kms)								
P77	BR1	Shale & siltstone	d +c + a + g + h	0.00	-0.15	-0.51	-0.65	-2.32	30.00	0.8467
		(Kms)								

d = dolomite; c = calcite; g = gypsum; a = anhydrite; h = halite

Table 6.1 Average chemical compositions of rain water in Hin Tank Hydrogeologic Province (averaged from 12 months : May 1989-April 1990)

No.	WELL NO	Head (m)	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	FpH mg/l	Fe mg/l	NO3 mg/l	SiO2 mg/l	Mn mg/l	Cu mg/l	Zn mg/l	F mg/l	Density (gm/cc)	FEc µS	TDS mg/l	Deuterium parts/1000	Oxygen parts/1000	Water Type
1	RW10		2.40	1.90	1	0.50	16.00	0	2.40	6.30										17			Ca-HCO3
2	RW16		8.00	3.30	1	0.30	14.00	8	3.00	8.50										38			Ca-HCO3-Cl
3	RW18		4.60	0.00	1	0.30	16.00	2	0.00	6.80										16			Ca-HCO3
4	RW19		6.60	0.50	2	0.70	22.00	0	2.20	7.80										26			Ca-HCO3
5	RW8		7.50	3.50	1	1.90	29.00	6	1.00	8.20										38			Ca-HCO3
6	RW9		12.00	1.20	1	0.70	41.00	1	0.00	7.60										36			Ca-HCO3

Table 6.2 Average chemical compositions of surface water in Hin Tank Hydrogeologic Province (averaged from 12 months : May 1989-April 1990)

No.	WELL NO	Head (m)	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	FpH mg/l	Fe mg/l	NO3 mg/l	SiO2 mg/l	Mn mg/l	Cu mg/l	Zn mg/l	F mg/l	Density (gm/cc)	FEc	TDS mg/l	Deuterium parts/1000	Oxygen parts/1000	Water Type
1	SW16		47.27	16.44	276	6.62	74.00	453	2.46	7.23	0.69	0.73	0.00	0.13	###	0.10	###		1818	892			Na-Cl
2	SW17		593.82	166.64	2124	66.91	17.44	4692	251.91	7.07	1.37	3.24	0.20	####	###	0.13	###		10164	7881			Na-Cl
3	SW22		36.33	9.78	124	3.94	97.50	220	17.69	7.48	1.19	0.46	1.40	0.32	###	0.00	###		833	375			Na-Cl
4	SW26		50.25	20.17	297	12.87	81.67	565	0.85	7.28	1.04	0.85	8.60	0.37	###	0.07	###		1892	987			Ca-Na-HCO3-Cl
5	SW29		2.6	1.4	4	3.9	14.0	3	10.0	7.0	1.60	1.0								32.0			Ca-Na-HCO3-Cl
6	SW30		15.0	3.1	64	6.1	115.0	79	5.7	6.9	7.90	8.5								238.0			Ca-Na-HCO3-Cl
7	SW35		29.0	5.2	62	17.0	75.0	128	6.0	7.1	9.70	0.7								284.0			Na-Cl
8	SW36		10.0	7.5	35	12.0	64.0	39	41.0	7.3	9.10	16.0								191.0			Na-Cl
9	SW37		36.0	6.4	103	6.9	63.0	232	4.0	7.4	8.10	0.5								419.0			Na-Cl

Table 6.3 Average chemical compositions of dug well water in Hin Tank Hydrogeologic Province (averaged from 12 months : May 1989-April 1990)

No.	WELL NO	Head (m)	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	FpH mg/l	Fe mg/l	NO3 mg/l	SiO2 mg/l	Mn mg/l	Cu mg/l	Zn mg/l	F mg/l	Density (gm/cc)	FEc µS	TDS mg/l	Deuterium parts/1000	Oxygen parts/1000	Water Type
1	DG16		75.00	3.20	1	16.00	197.00	36	8.30	7.20										266			Ca-HCO3
2	DG17		19.00	1.40	4	1.30	67.00	4	3.00	6.60										65			Ca-HCO3
3	DG18		15.00	7.40	18	36.00	106.00	19	3.00	8.80										164			Ca-Na-HCO3
4	DG19		1.90	2.40	4	1.10	11.00	7	6.90	5.50										29			Ca-Na-HCO3-Cl
5	DG9		7.00	0.70	3	3.10	17.00	9	1.20	6.60										33			Ca-Na-HCO3-Cl

Table 6.4 Average chemical compositions of groundwater in Hin Tank Hydrogeologic Province (averaged from 12 months : May 1989-April 1990)

No.	WELL No.	Head (m)	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	FpH mg/l	Fe mg/l	NO3 mg/l	SiO2 mg/l	Mn mg/l	Cu mg/l	Zn mg/l	F mg/l	Density (gm/cc)	FEc µS	TDS mg/l	Deuterium parts/1000	Oxygen parts/1000	Water Type
1	P75A	148.44	1670.00	228.90	1188	27.50	153.90	5283	2.83	6.92	2.45	3.57	42.00	1.80	0.07	0.28	0.10		11327	8477			Ca-Cl
2	B1060		584.50	115.33	284	5.96	390.75	1484	18.75	6.87	0.68	82.83	59.00	0.16	0.00		0.1		4650	2768			Ca-Cl
3	WW16	164.05	112.27	30.45	93	10.72	107.18	378	1.11	6.85	50.55	0.50	20.00	12.00	0.00	34.00	0.10		1545	678			Ca-Cl
4	F110		117.30	7.84	26	1.69	369.90	58	2.59	7.46	0.28	0.66							709	396			Ca-HCO3
5	B1118	191.61	200.27	29.22	35	11.15	454.45	160	8.53	6.88	2.81	131.64	66.00	0.05	0.00		0.1		1445	799	-48.00		Ca-HCO3
6	D555		104.50	15.70	20	5.03	453.00	10	1.78	7.09	2.78	0.97	48.00	0.02	0.00	0.98	0.10		670	379			Ca-HCO3
7	D65	196.29	70.17	15.67	40	4.48	399.75	6	1.10	7.20	11.96	0.44	49.00	0.07	0.00	0.49	0.10		625	334			Ca-HCO3
8	F366	162.44	36.83	5.57	8	1.68	157.08	6	0.92	7.18	10.73	0.57	61.00	0.08	0.00	0.92	0.20		250	135			Ca-HCO3
9	F701		84.83	15.67	31	3.93	377.17	31	0.65	7.02	4.11	3.20	83.00	0.07	0.00	0.84	0.10		692	355			Ca-HCO3
10	P52	185.11	84.45	14.70	31	9.04	395.36	27	2.19	6.95	1.51	1.48							655	365			Ca-HCO3
11	P53	194.70	90.18	32.09	37	3.06	521.18	14	0.98	7.06	0.12	5.75	48.00	0.05	0.01	0.16	0.20		809	439			Ca-HCO3
12	P79	199.40	85.64	19.82	34	5.43	447.82	13	1.28	7.18	1.13	1.97	29.00	0.62	0.01	0.68	0.10		682	381			Ca-HCO3
13	S233	193.72	84.09	15.73	24	4.23	397.00	11	0.84	6.83	7.78	0.43	56.00	0.08	0.00	0.34	0.10		673	331			Ca-HCO3
14	S473	196.79	132.67	27.11	24	6.22	400.44	77	2.79	6.93	1.80	34.83	58.00	0.09	0.01	1.90	0.10		920	494			Ca-HCO3
15	S649	168.95	97.10	13.95	40	2.66	479.92	7	1.04	7.24	11.10	0.50	56.00	0.45	0.00	0.86	0.10		692	398			Ca-HCO3
16	WW17	187.98	76.33	20.83	34	7.82	376.67	35	1.24	7.09	0.77	3.10	20.00	0.27	0.00	28.00	0.10		743	366			Ca-HCO3
17	WW18	189.04	100.67	15.33	25	4.93	423.67	12	3.33	7.30	0.75	0.60							617	368			Ca-HCO3
18	WW4	151.92	99.40	12.79	95	3.30	339.70	164	2.54	7.37	2.41	1.20	41.00	0.13	0.00	0.11	0.10		1060	546			Ca-HCO3
19	WW8	179.91	87.00	19.30	33	8.47	438.30	15	0.64	7.07	0.28	11.30	8.00	0.14	0.00	0.06	0.10		640	380			Ca-HCO3
20	WW9	171.81	90.50	14.84	19	5.36	388.25	16	1.30	6.94	6.01	0.86	57.00	0.08	0.00	0.31	0.10		625	338			Ca-HCO3
21	D739	190.05	141.83	31.67	38	11.62	260.50	139	4.28	6.92	3.80	206.33							1267	701			Ca-HCO3-Cl
22	D740	178.25	250.75	48.08	123	4.56	380.08	358	36.75	6.85	3.96	273.67	61.00	0.18	0.00	0.66	0.10		2173	1283			Ca-HCO3-Cl
23	D870	169.11	267.58	36.92	82	16.04	456.75	274	62.47	6.99	5.71	227.92	40.00	0.29	0.02	17.00	0.10		2050	1170			Ca-HCO3-Cl
24	PWLR	183.97	78.20	19.40	41	3.88	423.75	108	95.60	7.00		0.20	68.00	0.08	0.00	1.50	-		700	374			Ca-HCO3-Cl
25	S722	168.13	277.91	86.42	485	20.87	575.36	810	174.82	7.02	1.89	360.91	30.00	0.08	0.01	0.17	0.10		4120	2505			Ca-HCO3-Cl
26	P41	190.80	10.11	2.06	10	1.77	49.40	9	5.70	6.95	13.09	5.47	29.00	0.29	0.02	2.80	0.20		109	65			Ca-Na-HCO3
27	S809	164.16	61.08	16.75	67	4.57	443.75	8	1.20	7.29	3.63	0.59							717	378			Ca-Na-HCO3
28	D890	145.80	40.25	3.19	123	1.79	440.92	27	0.93	7.11	0.05	0.40	42.00	0.00	0.00	0.57	0.10		717	413			Ca-Na-HCO3
29	P84	152.14	18.82	1.61	45	1.64	164.45	15	1.98	7.26	1.11	0.77	36.00	0.16	0.00	0.12	0.30		405	164			Ca-Na-HCO3
30	P1	152.26	103.00	10.69	103	3.37	363.90	162	3.02	6.74	0.43	0.53	49.00	0.23	0.00	0.06	0.10		1079	562			Ca-Na-HCO3-Cl
31	P3	151.46	94.18	8.45	108	2.96	347.91	161	4.02	7.00	0.17	0.40	48.00	0.03	0.00	0.03	0.10		1036	551			Ca-Na-HCO3-Cl
32	P5	144.16	71.00	8.17	349	6.49	152.30	606	13.23	7.29	0.72	28.16	8.20	0.49	0.00	0.17	0.10		2300	1157	-59.00	-7.90	Ca-Na-HCO3-Cl
33	P6	151.19	87.36	7.02	76	3.20	329.36	100	1.42	7.21	0.36	0.46	50.00	0.26	0.03	0.37	0.30		850	404			Ca-Na-HCO3-Cl
34	P7	150.51	136.82	12.21	180	2.39	362.82	346	4.84	7.27	0.45	0.33	56.00	0.10	0.00	0.63	0.10		1562	862			Ca-Na-HCO3-Cl
35	P74	188.30	11.40	1.39	18	1.46	50.27	23	5.04	6.75	1.82	0.80	36.00	0.08	0.00	0.26	0.10		125	165			Ca-Na-HCO3-Cl
36	P8	150.70	95.67	26.00	626	2.89	382.11	953	14.78	7.36	0.62	1.19	41.00	0.09	0.00	0.16	0.0		10543	1907			Ca-Na-HCO3-Cl
37	WW3	151.77	100.09	11.00	90	3.22	326.00	163	1.53	7.16	3.44	0.73	31.00	0.18	0.00	2.10	0.10		1101	533			Ca-Na-HCO3-Cl
38	P43	164.84	80.82	8.68	36	5.31	251.27	83	1.63	6.79	3.04	1.60	69.00	1.04	0.02	0.44	0.10		645	342			Ca-Na-HCO3-Cl
39	P44	157.70	997.73	148.55	3235	48.90	215.82	6656	397.00	6.82	1.21	3.38	16.00	0.74	0.03	0.43	0.10		13555	11591			Na-Cl
40	P75	148.36	1070.60	166.70	352	15.80	119.20	2899	2.25	6.85	8.21	7.95	1.40	9.80	0.02	0.18	0.10	1.0059	6680.00	4572	-59.00		Na-Cl
41	P80	176.69	90.73	17.00	34	6.73	430.64	22	1.51	7.05	0.95	66.25	0.40	1.30	0.07	17.00	0.40		682	385			Na-Cl
42	B1059	158.75	169.5	48.2	474	8.2	269.7	827	238.9	8.40										1903.64			Na-Cl
43	D839	152.67	76.18	33.45	1055	3.12	513.55	1461	125.00	7.05	0.63	36.45	63.00	0.67	0.00	2.20	0.50		5155	3046			Na-Cl
44	D842	139.46	55.45	18.42	856	0.46	704.73	817	135.55	7.09	0.90	173.45	21.00	0.63	0.01	0.22	0.70		4009	2389			Na-Cl
45	D887	146.53	142.00	18.47	1145	10.36	247.50	861	1291.67	7.09	1.75	321.67	17.00	0.09	0.02	0.32	0.10		5458	3912			Na-Cl
46	D892	146.74	123.33	52.75	605	9.11	214.17	1142	70.75	6.98	30.01	0.97	8.00	0.76	0.01	0.62	0.10		3925	2110			Na-Cl
47	F804	164.04	123.92	12.36	302	4.83	296.50	516	47.58	7.28	0.57	0.74	48.00	0.01	0.00	0.13	0.1		1967	1154			Na-Cl
48	P83	144.84	2361.43	387.71	33596	207.86	156.57	75871	3659.71	6.69	3.87	69.60							14807	80486			Na-Cl-SO4
49	P85	151.77	484.00	98.36	2858	14.27	64.64	4624	1374.55	6.88	1.50	1.54	17.00	0.56	0.02	0.18	0.10		15045	9481			Na-Cl-SO4
50	P42	153.00	86.78	7.73	476	3.09	200.33	270	877.33	7.45	1.70	0.37	20.00	0.03	0.00	0.12	0.20		5031	1892			Na-SO4-Cl
51	P78	158.60	2100.00	151.27	2615	37.30	127.09	7315	806.18	6.81	2.17	2.21	0.56	0.03	0.24	0.20	0.20		15236	13155	-44.00		Na-Cl-SO4
52	P4	148.27	35.00	4.41	211	2.94	311.27	207	19.99	7.19	0.10	0.38	29.00	0.03	0.00	0.03	0.10		1214	635			Na-HCO3-Cl
53	S311	164.13	13.48	9.33	529	4.75	435.83	557	68.17	7.64	1.35	0.82	29.00	0.00	0.00	0.08	0.30		2550	1412			Na-HCO3-Cl

Table 6.5 Sequences of hydrochemical facies development for groundwater flow systems in Hin Tank Hydrogeologic Province

Regional System	Intermediate system	Local system	Areal area km^2	Hydrochemical Facies along flow paths
1. Ban Phai (CR1)			200	Ca-HCO_3 → Ca-Cl→ Na-Cl Ca-HCO_3 → Ca-Na-HCO_3→ Na-Cl Ca-HCO_3 → Ca-Na-HCO_3→ Na-SO_4-Cl
	Ban Thang Phat (CI1-1)		119	Ca-HCO_3 → Ca-Na-HCO_3-Cl→ Na-Cl
		Ban Hua Chang (CL1-1)	64	Ca-Na-HCO_3 → Na-Cl
		Ban Kham Pom (CL1-2)	53	Ca-HCO_3
2. Huai Toe(CR3)			112	Ca-HCO_3 → Ca-Na-HCO_3-Cl → Na-Cl
	Ban Nong Khai Nun (CI3-1)		56	Ca-HCO_3 → Ca-HCO_3-Cl → Ca-Na-HCO_3-Cl
		Hin Tank (CL3-1)	16	Ca-HCO_3
		Tha Phra (CL3-2)	8	Ca-HCO_3-Cl

Table 6.6 Characteristics of groundwater flow systems in Hin Tank Hydrogeolgic Province

Flow systems			Location	Area (As) (km2)	Aquifers	Porosity Sy	Piezometers and Wells	Flow direction	Flow path (Km)	Flow Depth (m)	Dhmin (m)	Kp (%)	qBmax (m/s)
Regional	Intermediate	Local											
CR1			Ban Phai	200	Tpt	0.12	WW17	E to W	15 to 20	160	0.09	2.95	7.34E-07
	CI1-1		Ban Thang Phat	120	Tpt	0.12	P79	E to W	10 to 20	120	0.01	0.33	6.52E-08
		CL1-1	Ban Huai Chang	50	Tpt	0.12	P43	E to W	5 to 8	40	0.08	2.62	6.52E-07
		CL1-2	Ban Kham Pom	65	Tpt	0.12	WW8	E to W	2 to 3	26	1.09*	35.67	1.78E-05
CR2			Amphoe Kosum Phisai	300	Tpt	0.1	WW18	W to E	20 to 25	170	0.56	15.27	3.94E-06
		CL2-1	Ban Khon Sak	150	Tpt	0.1	D739	W to E	1 to 3	25	1.67*	45.55	5.45E-05
		CL2-2	Huai Taen	30	Tpt	0.1	D740	W to E	3 to 5	50	2.23*	60.82	7.27E-06
CR3			Ban Huai Toei	115	Tpt	0.15	P74	S to N	10 to 20	160	0.86	35.18	5.04E-06
	CI3-1		Ban Nong Khai Nun	50	Tpt	0.15	P7	S to N	4 to 5	120	0.24	9.82	8.15E-07
		CL3-1	Ban Hin Tang	15	Tpt	NA	NA	S to N	NA	NA	NA	NA	NA
		CL3-2	Ban Tha Phra	5	Tpt	NA	NA	S to N	NA	NA	NA	NA	NA
		Total area of the province =		1100.00	km2					Average		23.13	1.01E-05

* = results of water level changes in these wells located in dischrge areas are substracted from the assumed evpotranspiration effect of 30%

As = total area of the flow system (km2)

Dc = depth of flow system across
the imaginary vertical plane, Ac (m)

Dhmin = minimum water level fluctuation during 4-month period

Sy = specific yield of rocks, values of Sy are assumed according to rock types as:

Kp = groundwater coeffcient of precipitation (%)

qBmax = maximum basin flux = qB*Ar/Ac (m/s)

Tpt Phu Tok Formation

NA = Data are not available

Table 6.7 Average chemical compositions of rain water in Hin Tank Hydrogeologic Province

	FLOW SYSTEM	TDS	Ca	Mg	Na	K	HCO3	Cl	SO4	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	Density	FEc	Deuterium	Oxygen	Water Type
							epm											(gm/cc)	μS	parts/1000	parts/1000	
RW18	CR1	16	0.23	0.00	0.04		0.26	0.06														Ca-HCO3
RW19	CR1	26	0.33	0.04	0.07		0.36	0.01														Ca-HCO3
RW8	CR1	38	0.37	0.29	0.05		0.48	0.17														Ca-HCO3
RW10	CR3	17	0.12	0.16	0.05	0	0.26	0.00	0	6.30												Ca-HCO3
RW16	CR3	38	0.40	0.27	0.04	0	0.23	0.24	0	8.50												Ca-HCO3
RW9	CR3	36	0.60	0.10	0.05	0	0.67	0.04	0	7.60												Ca-HCO3

Table 6.8 Average chemical compositions of individual major ions along the flow path for Ban Phai (CR1) and Huai Toei (CR3) regional systems in Hin Tank Hydrogeologic Province

		ppm					epm			m									(gm/cc)	μS	parts/1000	parts/1000	
WELL#	FLOW SYSTEM	TDS	Ca	Mg	Na	K	HCO3	Cl	SO4	HEAD	FpH	Fe	NO3	SiO2	Mn	Cu	Zn	F	Density	FEc	Deuterium	Oxygen	Water Type
WW18	CR1	368	5.02	1.26	1.09	0.13	6.94	0.32	0.07	189.04	7.30	0.75	0.60							617	-53.00		Ca-HCO3
WW17	CR1	366	3.81	1.71	1.46	0.20	6.17	0.99	0.03	187.98	7.09	0.77	3.10	20	0.27	0.00	28.00	0.1	1.0010	743	-61.00		Ca-HCO3
WW16	CR1	678	5.60	2.50	4.04	0.27	2.08	206.21	16.78	164.05	6.85	50.55	0.50	20	12.00	0.00	34.00	0.1		1545	-25.00		Ca-Na-Cl
P78	CR1	13155	104.79	12.44	113.76	0.95	3.54	187.64	8.27	158.60	6.82	1.21	3.38	0.74	0.03	0.43	0.1	0.1		13555	-44.00	-4.90	Na-Cl
P74	CR3	89	0.57	0.11	0.77	0.04	0.82	0.64	0.10	188.30	6.75	1.82	0.80	36	0.08	0.00	0.26	0.1		125			Ca-HCO3
PWLR	CR3	374	3.90	1.60	1.78	0.10	6.94	3.04	1.99	183.97	7.03	1.58	0.20	68	0.08	0.00	1.50	-		700			Ca-HCO3
WW4	CR3	546	4.96	1.05	4.15	0.08	5.57	4.62	0.05	144.16	7.37	2.41	1.20	41	0.13	0.00	0.11	0.1		1060			Ca-Na-HCO3-Cl
P5	CR3	1157	3.54	0.67	15.18	0.17	2.50	17.08	0.28	144.16	7.29	0.72	28.16	8.2	0.49	0.00	0.17	0.1		2300	-59.00	-7.90	Ca-Na-HCO3-Cl

Table 6.9 Ionic ratios for selected regional groundwater flow systems in Hin Tank Hydrogeologic Province (ionic ratios calculated in meq/l)

WELL#	FLOW SYSTEM	HCO3+SO4	Mg/Ca	Ca/Na	Ca/SO4	SO4/HCO3	HCO3/Cl	Cl/Ca	Cl/Na	Cl/K	Cl/SO4	Na+K	Na/Cl	Na-Cl	Ca+Mg	Ca/SO4	Mg/SO4	Ca+Mg/SO4
WW18	CR1	7.01	0.25	4.59	72.39	0.01	21.42	0.06	0.30	2.57	4.67	1.22	3.38	0.77	6.28	72.39	18.17	90.56
WW17	CR1	6.20	0.45	2.61	147.55	0.00	6.23	0.26	0.68	4.96	38.40	1.66	1.47	0.47	5.52	147.55	66.37	213.91
WW16	CR1	1.78	0.45	1.39	241.89	0.01	0.16	1.90	2.64	38.87	460.05	4.32	0.38	-6.61	8.11	241.89	108.13	350.02
P78	CR1	11.80	0.12	0.92	12.68	2.34	0.02	1.79	1.65	196.69	22.70	114.71	0.61	-73.88	117.23	12.68	1.51	14.18
P74	CR3	0.93	0.20	0.74	5.42	0.13	1.28	1.13	0.84	17.16	6.12	0.80	1.19	0.12	0.68	5.42	1.09	6.51
PWLR	CR3	8.93	0.41	2.19	1.96	0.29	2.28	0.78	1.71	30.68	1.53	1.88	0.59	-1.26	5.50	1.96	0.80	2.76
WW4	CR3	5.62	0.21	1.20	93.69	0.01	1.20	0.93	1.11	54.74	87.27	4.23	0.90	-0.47	6.01	93.69	19.87	113.56
P5	CR3	2.77	0.19	0.23	12.86	0.11	0.15	4.82	1.13	102.88	62.00	15.34	0.89	-1.90	4.21	12.86	2.44	15.30

Table 6.10 Saturation indices of groundwater with respect to dolomite, calcite, gypsum, anhydrite and halite for Ban Phai (CR1) and Huai Teoi (CR3) regional groundwater flow systems in Hin Tank Hydrogeologic Province

Well No.	Flow systems	Aquifers	Minerals	Saturation Index					T	Ionic strength
				SId	SIc	SIg	SIa	SIh	degree C	
WW18	CR1	Shale and sandstone (Tpt)	d +c + a +g	-0.39	0.00	-2.75	-2.91	-8.13	30.00	0.0070
WW17	CR1	Shale and sandstone (Tpt)	d +c + a +g	-0.66	-0.20	-3.14	-3.30	-7.52	30.00	0.0081
WW16	CR1	Shale and sandstone (Tpt)	d +c + a +g	-2.09	-0.91	-3.26	-3.42	-6.07	30.00	0.0159
P44	CR1	Shale and siltstone (Kms)	d +c + a +g	-0.65	-0.07	-0.47	-0.62	-3.46	30.00	0.2324
P74	CR3	Shale and sandstone (Tpt)	d +c + a +g	-5.03	-2.20	-3.18	-3.35	-7.94	30.00	0.0016
PWLR	CR3	Shale and sandstone (Tpt)	d +c + a +g	-0.81	-0.26	-1.36	-1.52	-6.96	30.00	0.0106
WW4	CR3	Shale and sandstone (Tpt)	d +c + a +g	-0.51	0.00	-2.91	-3.07	-6.40	30.00	0.0106
P5	CR3	Shale and sandstone (Tpt)	d +c	-1.61	-0.49	-2.32	-2.49	-5.78	30.00	0.0212

d = dolomite; c = calcite; g = gypsum; a = anhydrite; h = halite

Table 6.11 Results of model calibration and sensitivity analysis for groundwater hydraulic heads in Hin Tank Hydrogeologic Province

			m amsl				26 Layers			12 Layers					12 Layers				Model Head in m amsl			
No	Row	Column	M elev	M L	Well #	Meas head	refHT16.xyz	refC-1.xyz	refC-2.xyz	refC-3.xyz	refC-4.xyz	refC-5.xyz	refC-6.xyz	refC-7.xyz	refC-8.xyz	refC-9.xyz	ref-10.xyz	refC-11.xyz	refC-12.xyz	refC-13.xyz	refC-14.xyz	refC-D.xyz
1	12	7	90	8	P48	155.74	154.57	153.80	154.14	154.08	153.72	154.00	153.98	153.83	153.96	158.46	163.1	110.33	154.51	153.71	153.96	153.95
2	12	8	130	6	P44	157.59	155.15	155.04	155.12	155.09	155.02	155.00	155.01	155.05	155.35	157.25	160.02	138.23	155.62	155.17	155.1	155.12
3	12	11	150	10	WW16	162.32	167.05	164.55	165.96	165.63	164.23	163.01	163.05	163.46	164.97	166.55	165.28	89.14	165.32	164.32	163.62	164.86
4	12	11	110	7	P43	164.50	164.91	163.71	164.47	164.22	163.58	163.00	163.04	163.31	164.41	165.77	164.84	123.35	164.76	163.94	163.42	163.53
5	12	16	150	10	WW17	187.88	185.38	185.40	185.66	185.58	185.35	186.99	186.94	186.50	184.60	181.04	170.24	91.14	183.93	185.5	186.64	186.26
6	12	18	110	6	P80	177.88	180.54	180.30	180.44	180.38	180.29	180.00	180.05	180.40	181.91	183.46	177.68	140.9	182.51	181.24	180.53	180.49
7	26	22	110	7	WW18	187.30	197.21	197.24	197.29	197.26	197.24	198.00	197.95	197.[illegible]	195.77	192.03	179.65	126.34	194.96	196.64	197.66	197.67
8	26	22	110	7	WW18	187.30	197.21	197.24	197.29	197.26	197.24	198.00	197.95	197.59	195.77	192.03	179.65	126.34	194.96	196.64	197.66	197.67
9	13	22	130	6	PWLR	185.37	184.95	185.02	185.01	185.01	185.03	185.00	185.01	185.06	184.77	180.80	169.34	136.24	184.35	185.04	185.05	185.04
10	5	22	110	7	WW3	151.62	152.57	152.17	152.35	152.29	152.15	152.00	152.01	152.09	152.12	151.84	149.63	114.67	152.24	152.23	152.09	152.12
11	4	22	50	10	WW4	151.82	150.06	148.86	149.35	149.19	148.78	149.00	148.99	148.93	148.86	148.80	147.12	78.71	148.85	148.86	149.02	149.14
12	4	22	130	6	P5	151.20	149.03	148.99	149.01	149.00	148.99	149.00	149.00	148.98	148.93	148.86	148.34	130.71	148.91	148.94	149.01	149.01
13	3	22	90	8	P85	151.77	147.48	147.10	147.13	147.09	147.12	147.25	147.25	147.22	147.03	146.75	146.36	100.45	146.92	147.13	147.2	147.2
14	3	22	90	8	P84	152.14	147.48	147.10	147.13	147.09	147.12	147.25	147.25	147.22	147.03	146.75	146.36	100.45	146.92	147.13	147.2	147.2
15	2	23	90	8	P83	144.96	145.12	144.10	144.58	144.45	144.04	144.00	144.00	144.02	144.15	144.80	145.57	100.53	144.24	144.08	144.09	144.11
16	19	9	130	6	P42	152.78	152.03	152.02	152.02	152.02	152.02	152.00	152.00	152.01	152.23	153.56	155.94	137.56	152.4	152.08	152	152.01
17	18	12	130	6	S311	164.07	161.97	162.00	161.97	161.98	162.00	162.00	162.00	162.00	161.99	162.00	160.9	138.46	161.99	162	161.98	161.97
18	17	14	130	6	F110	169.00	168.79	168.83	168.79	168.81	168.83	169.00	168.97	168.76	167.80	165.93	162.48	138.16	167.34	168.23	168.93	168.83
19	7	19	130	6	C32KK1	164.00	163.68	163.83	163.72	163.77	163.84	164.00	163.98	163.78	162.67	160.02	155.2	132.8	162.04	163.2	163.81	163.74
20	5	18	90	8	PWDF	143.00	151.67	151.06	151.30	151.24	151.02	151.00	151.00	151.01	151.04	151.30	149.25	100.71	151.07	151.02	151.03	151.05
21	5	18	110	7	S913	141.40	151.39	151.03	151.20	151.14	151.01	151.00	151.00	151.00	151.03	151.20	149.77	114.77	151.05	151.01	151.02	151.04
22	10	35	110	7	P75A	148.04	147.86	147.80	147.75	147.77	147.80	148.00	147.98	147.88	147.75	148.82	150.29	116.04	147.83	147.74	147.9	147.89
23	10	35	130	6	P75	148.15	147.96	147.97	147.95	147.96	147.97	148.00	147.99	147.93	147.83	148.29	149.32	131.87	147.84	147.84	147.94	147.93
24	11	42	130	6	D842	139.22	141.06	141.03	141.04	141.03	141.02	141.00	141.00	141.03	141.23	142.22	145.06	130.68	141.36	141.13	141.02	141.03
25	17	46	130	6	D890	146.15	146.01	146.02	146.01	146.01	146.02	146.00	146.00	146.03	146.16	147.06	149.67	133.56	146.26	146.09	146.01	146.01
26	14	37	130	6	D887	146.21	149.06	149.02	149.04	149.03	149.02	149.00	149.00	149.01	149.20	150.31	151.98	133.7	149.37	149.09	149.01	149.02
27	18	45	130	6	D839	152.66	148.11	148.08	148.11	148.09	148.07	148.00	148.01	148.12	148.59	150.07	152.49	134.68	148.86	148.37	148.08	148.11
28	16	32	130	6	D740	177.06	174.51	174.68	174.54	174.61	174.70	174.99	174.93	174.50	173.19	170.89	165.13	136.85	172.62	173.7	174.62	174.51
		Mean error (ME)					-1.18	-0.83	-1.01	-0.95	-0.80	-0.88	-0.87	-0.85	-0.69	-0.29	2.39	41.09	-0.61	-0.77	-0.90	-0.94
		Mean absolute error (MAE)					3.10	3.05	3.06	3.06	3.04	2.95	2.95	2.99	3.12	3.49	5.29	41.09	3.19	3.07	2.98	3.05
		Root mean squared rror (RMS)					4.52	4.42	4.48	4.46	4.41	4.50	4.49	4.44	4.25	4.36	6.87	46.19	4.21	4.32	4.46	4.48

Results of simulation of 26 model layers

refHT-16.xyz for Kx=Ky and Kz =1E-2 m/d

Results of simulation of 12 model layers

refC-1.xyz for Kx-Ky and Kz = 3.0E-1 m/d or Vcont =1.5E-2

Results of simulation of 12 model layers

and variaton of horizontal anisotropy (Kx or Ky)

refC-2.xyz for Kx= 10x Ky and Kz =3.0E-1 m/d or Vcont=1.5E

refC-3.xyz for Kx= 5x Ky and Kz =3.0E-1 m/d or Vcont=1.5E-

refA-4.xyz for Kx= 0.5x Ky and Kz =3.0E-1 m/d or Vcont=1.5

Results of simulation of 12 model layers and variaton in Kz

refC-5.xyz for Kx=Ky and Kz = 2E+1 m/d or Vcont =1.0

refC-6.xyz for Kx= Ky and Kz = 2.0 E+0 m/d or Vcont= 1.0E-1

refC-7.xyz for Kx= Ky and Kz = 4.0E-1 m/d or Vcont= 1.0E-2

refC-8.xyz for Kx= Ky and Kz = 2.0E-2 m/d or Vcont= 1.0E-3

refC-9.xyz for Kx= Ky and Kz = 2.0E-3 m/d or Vcont= 1.0E-4

refC-10.xyz for Kx= Ky and Kz = 2.0E-4 m/d or Vcont= 1.0E-5

refC-11.xyz for Kx= Ky and Kz = 2.0E-5 m/d or Vcont= 1.0E-6

refC-D.xyz for Kx= Ky and Kz = 0.3 m/d(Layer # 1 - 8 or Vcont= 1.0E-2 and

Results of simulation of 12 model layers

and double and half of Kx and Ky values

refC-12.xyz = double Kx and Ky values (the rest para = refC-8.xyz)

refC-12.xyz = half Kx and Ky values (the rest para = refC-8.xyz)

Results of simulation of 12 model layers and

homogeneous case , Kx=Ky=Kz=1 m/d

refC-14.xyz = for Kx=Ky=0.5 m/d and Kz = 0.4 or Vcont= 1.0E-2

Table 6.12 Hydrogeologic parameters of flow systems determined by mapping or piezometric analysis and 3-D models for Hin Tank Hydrogeologic Province

	Piezometric analysis			A Steady 3-D Model		
Hydraulic parameters	Ban Phai R. S. CR1	Kosum Phisai CR2	Huai Toei CR3	Ban Phai R.S. RC1	Kosum Phisai CR2	Huai Toei CR3
Flow path (Km)	15 - 20	20 -25	10 - 20	?	?	?
Flow depth (m)	160	170	160	< 200	<200	<190
Flux (m/s) Vx	7.34E-07	3.94E-06	5.04E-06	2.30E-11 -5.0E-08 (4.86E-07)	1.00E-11 - 1.5E-08 (2.0E-06)	1.30E-09 - 1.00E-07 (3.59E-06)
Vy				1.16E-11 - 2.31E-07 (5.20E-07)	1.16E-10 - 3.60E-07 (2.30E-06)	2.00E-09 - 1.13E -07 (5.08E-06)
Vz				7.00E-12 - 3.50E-08 (2.50E-09)	2.31E-12 - 2.31E-10 (1.04E-08)	1.00E-10 - 4.20E-08 (3.0E-08)
Flow direction	C → W	C → E	C → N	C → W	C → E	C → N
Recharge rate (m/s)	1.03E-09	5.33E-09	1.22E-08	> 0.00 -8.00E-09	> 0.00 - 7.50E-09	> 0.00 -2.0E-08
GW. Coef. of precipitation (%)	2.95	15.27	35.18	> 0.00 - 23.00	> 0.00 - 21.5	> 0.00 - 58

Numbers in brackets are averaged from the value ranges in an individual flow system.

Table 7.1 Physical properties of the hydrogeologic provinces in the Khon Kaen Drainage Basin

	Hydrogeologic provinces		
Topography	**Huai Yai**	**Chonnabot**	**HinTank**
Topographic expression	sinusoidal and simple	sinusoidal	sinusoidal
Topographic elevation range in m(amsl.)	230 - 150	240 - 140	240 -150
Regional surface slope	0.0007 - 0.002	0.001 - 0.007	0.001 - 0.003
	low	high	medium
Area (km 2)	830	176	1110
Recharge area ,RA (km2)	270.00	120	630
Discharge area, DA (km2)	560	56.00	480.00
RA : DA	1 : 2	1 : 0.46	1 : 0.76
Depth : width	1 : 166	1: 62	1:187
Boundaries			
North	Nong Lup Ridge	Stream (fault)	Chi River (fault zone)
South	Stream(fault)	Chi River (fault zone)	Huai Kut Chuak (fault)
East	Chi River (fault zone)	Chi River (fault zone)	Huia Taen (fault)
West	Phu Meng Ridge	Stream	Chi River (fault zone)
Geology and Hydrogeologic units			
Geologic structures	Broad syncline & anticline restricted fractures	Anticline	Broad syncline, flat, extensive restricted fractures
Aquifers	Qgs (sand & gravel)	Kms (ss, silts & sh)	Tpt (silts & sh)
	Kms (ss, silts & sh)		
	Kpp (congl ss)		
Aquitards	Kms(rocksalt) Kkk (sh & silts) Jpk (sh & silts)	Kkk (sh&silts)	Kms (ss, silts & sh
AclicIude	rs (rock salt)	rs	rs

Table 7.1 (cont.)

	Hydrogeologic provinces		
Flow Regimes	**Huai Yai**	**Chonnabot**	**HinTank**
Water table depth			
in recharge area m below gs	5 -15	4 - 18	5 - 15
TDS (mg/l)	< 1050	< 700	< 500
in discharge area m below gs	< 1.5	< 1.0	< 1.5
TDS (mg/l)	> 1050	> 700	> 500
Flow Systems			
Local flow systems	AL1-1, AL1-2, AL3-1	BL1-1	CL1-1, CL1-2, CL2-1,
			CL2-2, CL3-1& CL3-2
Flow path length (km)	0.5 - 2.0	0.5 - 2.0	1.0 - 8 .0
Flow depth (m)	30.0 - 40.0	40.00	10.0 - 50.0
Intermediate flow systems	AI1-1, A2-1, AI3-1& AI3-2		CI1-1 & CI3-1
Flow path length (km)	5.0 - 20.0	5	3.0 - 10.0
Flow depth (m)	60.0 - 80.0	110	110.0 - 120.0
Regional flow systems	AR1, AR2 & AR3	BR1	CR1, CR2 &CR3
Flow path length (km)	8.0 - 40.0	8.0 - 10.0	10.0 - 25.0
Flow depth (m)	150 .0 - 170.0	170.0	160.0 - 170.0
Ground water Balance			
Annual rainfall (mm)	1178.4	1150	1100
Coefficienct of precipitation (Kp, %)	28.2	10.35	22.10
Natural basin yield (l/s)	3.04E+03	3.36E+02	4.12E+03
Safe Rate of Production (l/s)	3.43E+01	7.70E+00	4.35E+01
Maximum basin flow velocity (m/s)	4.61E-06	1.54E-06	9.25E-06
Regional hydraulic conductivity (m/s)	2.32E-06	6.47E-07	2.32E-06
Names of the flow systems RFS = Regional flow system IFS = Intermediate flow system LFS = Local flow system	AR1 = Phu Meng RFS AI1-1 = Ban Khok Kwang IFS AL1-1 = Ban Fang LFS AL1-2 = Ban Muang LFS AR2 = Ban Nong Wang Hi RFS AI2-1 = Ban Kham Pom IFS AR3 = Nong Lup RFS AI3-1 = Ban Sri Than IFS AL3-1 = Ban Sa Art LFS	BR1 = Huai Hin Keang RFS BL1-1 = Ban Nong Ben LFS	CR1 = Ban Phai RFS CI1-1 = Ban Thang Phat IFS CL1-1 = Ban Hua Chang LFS CL1-2 = Ban Kham Pom LFS CR2 = Kosum Phisai RFS CL2-1 = Ban Khon Sak LFS CL2-2 = Huai Taen LFS CR3 = Huai Toe RFS CI3-1 = Ban Nong Khai Nun IFS CL3-1 = Hin Tank LFS CL3-2 = Tha Phra LFS

Table 7.2 Relationship between Recharge and Discharge Areas and other surface manifestations in the Khon Kaen Drainage Basin

1. Recharge area locations

	Huai Yai	**Chonnabot**	**Hin Tank**
High elevations (m amsl)	>180 (85%)	>180 (78%)	>180 (80%)
Soil-drainage classes	WDS (76%)	WDS (80%)	NA
Soil Salinity Indices	4, 5 (40%)	4 (60%)	5 (80%)
Land Types	Rv (21%), R (36%) & Gu (37%), 94%	Rv (15%), R (42%) & Gu (30%), 87%	R (11%), Gu (65%), 76%
Surface Water Quality	Ca-HCO3	Ca-HCO3	Ca-HCO3

2. Discharge area locations

	Huai Yai	**Chonnabot**	**Hin Tank**
Low elevations (m amsl)	<180 (93%)	<180 (93%)	<180 (88%)
Soil-drainage classes	PDS (65%) & VPDS (10%), 75%	PDS (48%),VPDS (22%), 70%	NA
Soil Salinity Indices	1-->4 (66%)	1-->4 (67%)	1-->5 (97%)
Land Types	Fp (55%), A (20%)& Rm (15%) , 90%	Fp (30%), Rm (57%), 87%	Fp (24%), A (18%)& Rm (38%), 80%
Surface Water Quality	Na-Cl	Na-Cl & Na-Cl-SO4	Na-Cl & Na-Cl-SO4
Salt tolerant plants	Azima sarmentosa Gisekia pharmacoides Maytenus mekokgensis Plucea indica Synostemon bacciformis Massia triseta	Azima sarmentosa Maytenus mekokgensis	Azima sarmentosa Gisekia pharmacoides Maytenus mekokgensis Plucea indica Synostemon bacciformis Massia triseta Fimbristylis Hookeriana
Other features	Termite mounds salt havesting sites		Soap holes, tree lineations, and joint sets

Where:

Soil-drainage classes
WDS: Very well Drained Soil
PDS: Poorly Drained Soil
VPDS: Very Poorly Drained Soil

Land Types
R: High and broad ridge (6-9% slope)
Gu: Gentle undulating to high plains (2-5% slope)
Fp: Flood plain with gentle to nearly slope and locally salt affected(0.5-5% slope)
A: Alluvium plains along major streams (0-0.5% slope)

Soil salinity indices
1: Highly salinised soil
2: Moderately salined soil
3: Slightly salinised soil
4: Low topograhy, moderately salinised soil
5: High topography underlain by rock salt
6: No indication of salinised soil

Table 7.3 Estimation of hydraulic parameters and water balance in Huai Yai Hydrogeologic Province

a.) Groundwater coefficient of precipitation (Kp)

Ab (km 2)	830.00
Ar (km2)	270.00
Ad (km2)	560.00
Ar/Ab	0.33

	< system A1			>	< system A2			>	< system A3			>
No. of flow systems	AR1	AI1-1	AL1-1	AL1-2	AR2	AI2-1	AR3	AI3-1	AI3-2	AL3-2	average	Total
As, (km2)	185	130	100	30	125	50	110	60	30	10		
Dc (m)	155	80	32	42	157	67	166	80	67	34		
Dhmin (m)	1.63	0.77	1.53	0.77	0.29	2.12	0.06	0.62	1.01	0.88	0.97	
Sy (porosity)	0.12	0.12	0.15	0.1	0.1	0.1	0.15	0.12	0.1	0.1	0.12	
sr,t (m)	0.1956	0.0924	0.2295	0.077	0.029	0.212	0.009	0.0744	0.101	0.088	0.11	
qB(m/a)	0.5868	0.2772	0.6885	0.231	0.087	0.636	0.027	0.2232	0.303	0.264	0.33	
qB (m/s)	1.8607E-08	8.79E-09	2.1832E-08	7.325E-09	2.7588E-09	2.0167E-08	8.5616E-10	7.0776E-09	9.6081E-09	8.3714E-09	1.05E-08	
VBt (m3/4-m)	1.18E+07	3.91E+06	7.47E+06	7.51E+05	1.18E+06	3.45E+06	3.22E+05	1.45E+06	9.86E+05	2.86E+05		3.16E+07
p (m/a)	1.1784	1.1784	1.1784	1.1784	1.1784	1.1784	1.1784	1.1784	1.1784	1.1784		
Kp, (%) average	49.80	23.52	58.43	19.60	7.38	53.97	2.29	18.94	25.71	22.40	28.21	
ir	2.22E-03	1.85E-03	1.11E-03	7.11E-04	1.90E-03	1.48E-03	4.44E-03	3.56E-03	1.56E-03	1.78E-03	2.06E-03	

b.)Estimation of basin yield (qB), safe rate of production (qBsafe and actual flow-velocity (vBmax)

	AR1	AI1-1	AL1-1	AL1-2	AR2	AI2-1	AR3	AI3-1	AI3-2	AL3-2	average	Total
qB (m3/s.km2)	1.86E-02	8.79E-03	2.18E-02	7.32E-03	2.76E-03	2.02E-02	8.56E-04	7.08E-03	9.61E-03	8.37E-03	1.05E-02	
QB (m3/s)	1.14	0.38	0.72	0.07	0.11	0.33	0.03	0.14	0.10	0.03		3.04E+00
QB (l/s)	1135.35	376.88	720.07	72.48	113.74	332.58	31.06	140.06	95.07	27.61		3.04E+03
qBsafe (m3/s.km2)	6.05E-03	2.86E-03	7.10E-03	2.38E-03	8.97E-04	6.56E-03	2.79E-04	2.30E-03	3.13E-03	2.72E-03		3.43E-02
qBsafe (l/s.km2)	6.05E+00	2.86E+00	7.10E+00	2.38E+00	8.97E-01	6.56E+00	2.79E-01	2.30E+00	3.13E+00	2.72E+00		3.43E+01
QiT (m3/s)	1.12E+00	3.72E-01	7.10E-01	7.15E-02	1.12E-01	3.28E-01	3.06E-02	1.38E-01	9.38E-02	2.72E-02		3.00E+00
QiT (l/s)	1.12E+03	3.72E+02	7.10E+02	7.15E+01	1.12E+02	3.28E+02	3.06E+01	1.38E+02	9.38E+01	2.72E+01		3.00E+03
qBmax (m/s)	7.32E-06	4.71E-06	2.25E-05	1.73E-06	7.24E-07	4.96E-06	1.87E-07	1.75E-06	1.42E-06	8.12E-07	4.61E-06	
vBmax (m3/s.km2)	6.10E-05	3.93E-05	1.50E-04	1.73E-05	7.24E-06	4.96E-05	1.25E-06	1.46E-05	1.42E-05	8.12E-06	3.63E-05	
vBmax (m/s)	6.10E-11	3.93E-11	1.50E-10	1.73E-11	7.24E-12	4.96E-11	1.25E-12	1.46E-11	1.42E-11	8.12E-12	3.63E-11	
KB (m/s)	2.72E-06	1.54E-06	6.39E-06	3.35E-06	4.71E-07	4.43E-06	6.27E-08	6.48E-07	2.01E-06	1.53E-06	2.32E-06	

where:

Ab = total area of the province (km2)

As = total area of the flow system km2)

Ar = recharge area (km2)

Ad = discharge area (km2)

Dc = depth of flow system across

the imaginery vertical plane, Ac (m)

Dhmin = minimum water level fluctuation during 4-month period

Sy = specific yield of rocks, values of Sy are assumed according to rock types as:

as:Sy of Qsg = 0.15: Jsk, Jpw and Kkk = 0.1, Kpp = 0.12, and Kms = 0.1

s r,t=4 months : depth of water in the recharge areas transfered

to discharge areas during time, t

qB = specific basin yield (m/s)

VBt = sr,t*Ar*(Ar/Ab)*1000*1000/(m3/4-m)

p= the depth of precipitation during the time interval T (m/a)

Kp = groundwater coeffcient of precipitation (%)

ir = regional hydraulic gradient of the flow system

QB = natural basin yield = Vbt*1000/(t*4*30*24*60*60) (l/s)

QiT = Total safe basin yield (m3/d)

Ac= Dc*1000 , width of the flow system is 1 km

qBmax = maximum basin flux = qB*Ar/Ac (m3/d.km2)

vBmax = maximum basin flow-velicity

or actual flow-velocity = qBmax/Sy (m3/d.km2)

qBmax (m/s)= qBmax /(1000*1000)

vBmax (m/s) = vBmax/(1000*1000)

KB = qBmax/ir (m/s)

Table 7.4 Estimation of hydraulic parameters and water balance in Chonnabot Hydrogeologic Province

a.) Groundwater coefficient of precipitation (Kp)

Ab (km 2)	176.37			
Ar (km2)	120			
Ad (km2)	56.37			
Ar/Ab	0.68			
	< Regional system B1 >			
No. of flow systems	BR1	BL1-1	average	Total
As, (km2)	146	30		1.76E+02
Dc, (m)	170	40		
Dhmin (m)	0.13	0.51	0.32	
Sy (porosity)	0.1	0.1	0.10	
sr,t (m)	0.013	0.051	0.03	
qB(m/a)	0.039	0.153	0.10	
qB (m/s)	1.23668E-09	4.8516E-09	3.04E-09	
VBt (m3/4-m)	1.29E+06	1.04E+06		2.33E+06
p (m/a)	1.15	1.15		
Kp, (%) average	3.39	13.30	8.35	
ir	6.99E-03	2.69E-03	4.84E-03	

b.)Estimation of basin yield (qB), safe rate of production (qBsafe and actual flow-velocity (vBmax)

qB (m3/s.km2)	1.24E-03	4.85E-03	3.04E-03	
QB (m3/s)	0.12	0.10		2.25E-01
QB (l/s)	124.55	100.40		2.25E+02
qBsafe (m3/s.km2)	8.41E-04	3.30E-03		4.14E-03
qBsafe (l/s.km2)	8.41E-01	3.30E+00		4.14E+00
QiT (m3/s)	1.23E-01	9.90E-02		2.22E-01
QiT (l/s)	1.23E+02	9.90E+01		2.22E+02
qBmax (m/s)	7.33E-07	2.51E-06	1.62E-06	
vBmax (m3/s.km2)	7.33E-06	2.51E-05	1.62E-05	
vBmax (m/s)	7.33E-12	2.51E-11	1.62E-11	
KB (m/s)	1.20E-07	1.23E-06	6.73E-07	

where:

Ab = total area of the province (km2)
As = total area of the flow system km2)
Ar = recharge area (km2)
Ad = discharge area (km2)
Dc = depth of flow system across
the imaginery vertical plane, Ac (m)
Dhmin = minimum water level fluctuation during 4-month period
Sy = specific yield of rocks, values of Sy are assumed according to rock types as:
as:Sy of Qsg = 0.15: Jsk, Jpw and Kkk = 0.1, Kpp = 0.12, and Kms = 0.1
s r,t=4 months : depth of water in the recharge areas transfered
to discharge areas during time, t
qB = specific basin yield (m/s)
VBt = sr,t*Ar*(Ar/Ab)*1000*1000/(m3/4-m)

VBt = sr,t*Ar*(Ar/Ab)*1000*1000/(m3/4-m)
p= the depth of precipitation during the time interval T (m/a)
Kp = groundwater coeffcient of precipitation (%)
ir = regional hydraulic gradient of the flow system
QB = natural basin yield = Vbt*1000/(t*4*30*24*60*60) (l/s)
QiT = Total safe basin yield (m3/d)
Ac= Dc*1000 , width of the flow system is 1 km
qBmax = maximum basin flux = qB*Ar/Ac (m3/d.km2)
vBmax = maximum basin flow-velicity
or actual flow-velocity = qBmax/Sy (m3/d.km2)
qBmax (m/s)= qBmax /(1000*1000)
vBmax (m/s) = vBmax/(1000*1000)
KB = qBmax/ir (m/s)

Table 7.5 Estimation of hydraulic parameters and water balance in Hin Tank Hydrogeologic Province

a.) Groundwater coefficient of precipitation (Kp)

Ab (km 2)	1100.00													
Ar (km2)	620.00													
Ad (km2)	480.00													
Ar/Ab	0.56													
	<	system C1		>	<	system C2		>	<	system C3		>		
No. of flow systems	CR1	CI1-1	CL1-1	CL1-2	CR2	CL2-1	CL2-2	CR3	CI3-1	CL3-1	CL3-2	average	Total	WELLNO
As, (km2)	200	120	50	65	300	150	30	115	50	15	5		1100	P52
Dc (m)	160	120	40	26	170	25	50	160	120	NA	NA			P79
Dhmin (m)	0.09	0.01	0.08	1.09	0.56	1.67	2.23	0.86	0.24	NA	NA	0.76		WW8
Sy (porosity)	0.12	0.12	0.12	0.12	0.1	0.1	0.1	0.15	0.15	NA	NA	0.12		WW18
sr,t (m)	0.0108	0.0012	0.0096	0.1308	0.056	0.167	0.223	0.129	0.036	NA	NA	0.08		
qB(m/a)	0.0324	0.0036	0.0288	0.3924	0.168	0.501	0.669	0.387	0.108	NA	NA	0.25		
qB (m/s)	1.0274E-09	1.142E-10	9.132E-10	1.2443E-08	5.3272E-09	1.589E-08	2.1214E-08	1.2272E-08	3.4247E-09	NA	NA	8.07E-09		
VBt (m3/4-m)	1.22E+06	8.12E+04	2.71E+05	4.79E+06	9.47E+06	1.41E+07	3.77E+06	8.36E+06	1.01E+06	NA	NA		4.31E+07	
p (m/a)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1			P74
Kp, (%) average	2.95	0.33	2.62	35.67	15.27	45.55	60.82	35.18	9.82	NA	NA	23.13		WW4
ir	2.86E-03	2.29E-03	1.00E-03	1.00E-03	3.14E-03	1.78E-03	2.22E-03	4.44E-03	3.56E-03	1.78E-03	1.33E-03	2.31E-03		
b.)Estimation of basin yield (qB), safe rate of production (qBsafe and actual flow-velocity (vBmax)														
qB (m3/s.km2)	1.03E-03	1.14E-04	9.13E-04	1.24E-02	5.33E-03	1.59E-02	2.12E-02	1.23E-02	3.42E-03	NA	NA	8.07E-03		
QB (m3/s)	0.12	0.01	0.03	0.46	0.91	1.36	0.36	0.81	0.10	NA	NA		4.16E+00	
QB (l/s)	117.42	7.83	26.09	462.19	913.30	1361.80	363.69	806.48	97.85				4.16E+03	
qBsafe (m3/s.km2)	5.79E-04	6.43E-05	5.15E-04	7.01E-03	3.00E-03	8.95E-03	1.20E-02	6.92E-03	1.93E-03	NA	NA		4.09E-02	
qBsafe (l/s.km2)	5.79E-01	6.43E-02	5.15E-01	7.01E+00	3.00E+00	8.95E+00	1.20E+01	6.92E+00	1.93E+00	NA	NA		4.09E+01	
QiT (m3/s)	1.16E-01	7.72E-03	2.57E-02	4.56E-01	9.01E-01	1.34E+00	3.59E-01	7.95E-01	9.65E-02	NA	NA		4.10E+00	
QiT (l/s)	1.16E+02	7.72E+00	2.57E+01	4.56E+02	9.01E+02	1.34E+03	3.59E+02	7.95E+02	9.65E+01	NA	NA		4.10E+03	
qBmax (m/s)	7.34E-07	6.52E-08	6.52E-07	1.78E-05	5.37E-06	5.45E-05	7.27E-06	5.04E-06	8.15E-07	NA	NA	1.02E-05		
vBmax (m3/s.km2)	6.12E-06	5.44E-07	5.44E-06	1.48E-04	5.37E-05	5.45E-04	7.27E-05	3.36E-05	5.44E-06	NA	NA	9.67E-05		
vBmax (m/s)	6.12E-12	6.29E-18	6.29E-17	1.71E-15	6.22E-16	6.30E-15	8.42E-16	3.89E-16	6.29E-17	NA	NA	6.81E-13		
KB (m/s)	2.02E-07	3.26E-13	5.96E-12	8.12E-11	1.11E-11	5.83E-11	6.23E-11	1.80E-11	6.28E-12	NA	NA	2.25E-08		

where:

Ab = total area of the province (km2)
As = total area of the flow system km2)
Ar = recharge area (km2)
Ad = discharge area (km2)
Dc = depth of flow system across
the imaginery vertical plane, Ac (m)
Dhmin = minimum water level fluctuation during 4-month period
Sy = specific yield of rocks, values of Sy are assumed according to rock types as:
as:Sy of Qsg = 0.15: Jsk, Jpw and Kkk = 0.1, Kpp = 0.12, and Kms = 0.1
s r,t=4 months : depth of water in the recharge areas transfered
to discharge areas during time, t
qB = specific basin yield (m/s)

VBt = sr,t*Ar*(Ar/Ab)*1000*1000/(m3/4-m)
p= the depth of precipitation during the time interval T (m/a)
Kp = groundwater coeffcient of precipitation (%)
ir = regional hydraulic gradient of the flow system
QB = natural basin yield = Vbt*1000/(t*4*30*24*60*60) (l/s)
QiT = Total safe basin yield (m3/d)
Ac= Dc*1000 , width of the flow system is 1 km
qBmax = maximum basin flux = qB*Ar/Ac (m3/d.km2)
vBmax = maximum basin flow-velicity
or actual flow-velocity = qBmax/Sy (m3/d.km2)
qBmax (m/s)= qBmax /(1000*1000)
vBmax (m/s) = vBmax/(1000*1000)
KB = qBmax/ir (m/s)

Table 7.6 Groundwater balance determined by field and numerical techniques in the Khon Kaen Drainage Basin

Parameters		Field techniques			Numerical Simulations	
		Huai Yai	Chonnabot	Hin Tank	Huai Yai	Hin Tank
1. Average depth of annual water level changes	$\overline{S}r, t$ (m)	.97 (0.06 to 2.12)	3.72 (0.6 to 6.8)	5.00 (0.2 to 16.2)		
2. Groundwater coefficient of precipitation	Kp(%)	28.21 (2.29 to 53.97)	10.35. (3.35 to 14.35)	22.10 (0.33 to 60.82))		> 0 to 44.1
3. Natural basin yield	Q_B (l/s)	3.04E+03	3.36E+02	4.12E+03	$0.53 x 10^6$	$2.33 x 10^6$
4. Specific basin yield	q_B (m/s.km^2)	1.05E+01 (8.56E-01 to 2.18E +01)	3.77E+00 (1.27 to 5.23)	7.71E+00 (1.14E-01 to 2.12E+01)		
5. Safe basin yield	QiT (l/s)	3.43E+01	7.70E+00	4.35E+01		
Vx					4.4E-08 (2.78E-13 - 5.79E-08))	4.4E-08 (3.47E-11 - 2.75E-07)
6 Flux (m/s) Vy	q_{Bmax} (m/s)	4.61E-06	1.54E-06	9.25E-06	4.2E-08 (1.10E-13 - 2.59E-08)	4.2E-08 (1.16E-13 - 3.25E-07)
Vz					8.45E-10 (2.31E-16-1.85E-08)	2.43E-10 (8.10E-12 - 3.82E-09)
7. Regional hydraulic conductivity	K_B (m/s)	2.32E-06	6.47E-07	2.32E-06)		
8. Precipitation	m/a	1.1784	1.1500	1.1000		
9. Total area	Km^3	830	176	1110		
10. RA : DA		1:2	1:0.47	1:0.78		
11. Area of surface water	Km^3	27	5	10		
12. Evaporation (m/a)	E (m/a)	2.020	2.020	2.020		
13.Potential Evapotranspiration (m/a)	E'+E"	1784.5	1784.5	1784.5		
14. Surface runoff (m/a)	(Qs)					

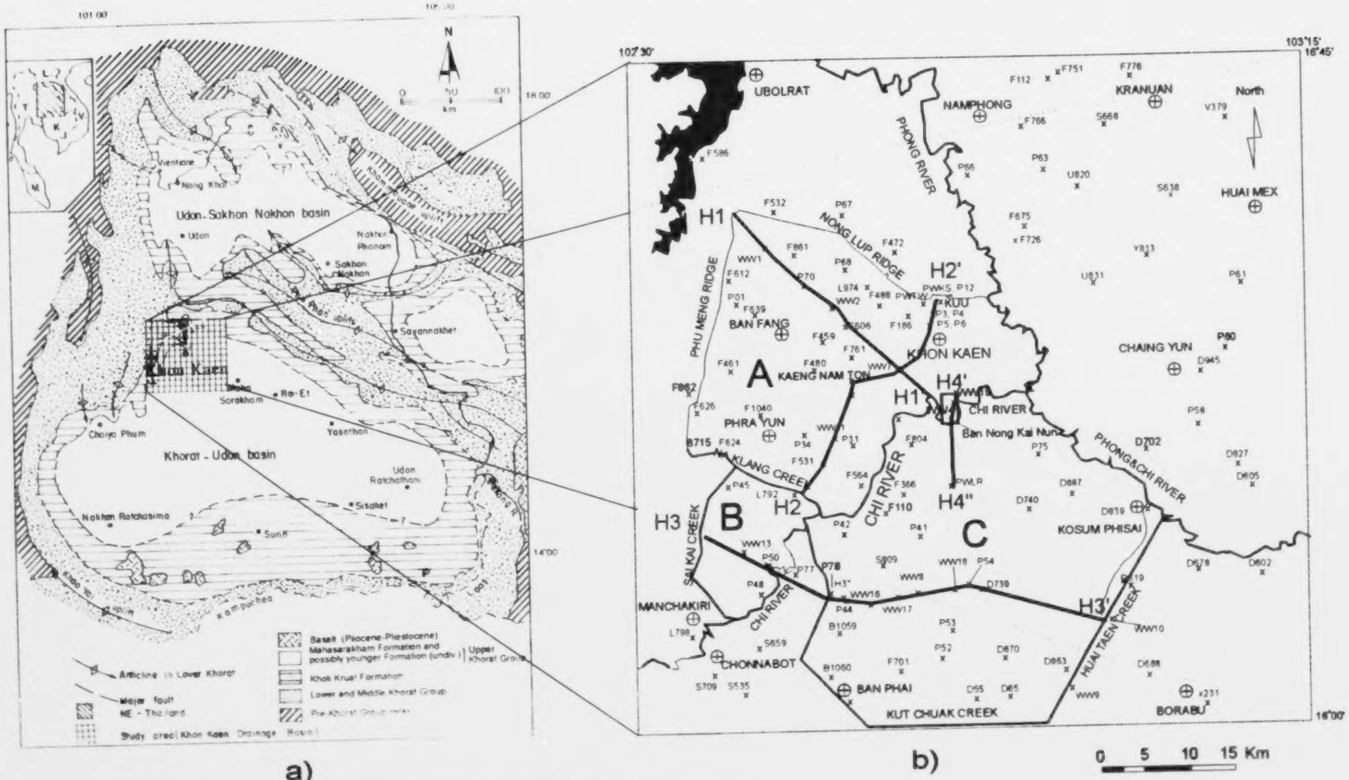

a)
Udon-Sakhon Nakhon basin
Khorat - Udon basin
Vientiane
Nong Khai
Udon
Nakhon Phanom
Sakhon Nakhon
Savannakhet
Khon Kaen
Chaiya Phum
Roi-Et
Yasothon
Udon Ratchathani
Nakhon Ratchasima
Surin
Sisaket
Kampuchea
Basalt (Pliocene-Pleistocene)
Mahasarakham Formation and possibly younger Formation (undiv.)
Upper Khorat Group
Khok Kruat Formation
Lower and Middle Khorat Group
Pre-Khorat Group rocks
Anticline in Lower Khorat
Major fault
NE - Thailand
Study area (Khon Kaen Drainage Basin)
b)
UBOLRAT
NAMPHONG
KRANUAN
HUAI MEX
CHAING YUN
KHON KAEN
BAN FANG
KAENG NAM TON
PHRA YUN
MANCHAKIRI
CHONNABOT
BAN PHAI
KOSUM PHISAI
BORABU
PHONG RIVER
CHI RIVER
PHONG&CHI RIVER
NONG LUP RIDGE
PHU MENG RIDGE
KLANG CREEK
SAI KAI CREEK
KUT CHUAK CREEK
HUAI TAEN CREEK
Ban Nong Kai Nun
A
B
C
H1
H1'
H2
H2'
H3
H3'
H4'
H4''
North
102°30'
103°15'
16°45'
16°00'
0 5 10 15 Km

Figure 1.1 Location map of the study area
a) Geologic map of the Khorat Plateau, Northeast Thailand
(modified from Japakasert and Workman, 1981)
b) Khon Kaen Drainage Basin and Ban Nong Khai Nun

☐	Ban Nong Khai Nun
	Hydrogeologic provinces
A	Huai Yai
B	Chonnabot
C	Hin Tank

~	River and stream
H1 ——— H1'	Line of hydrogeologic profile
WW, PW	Water wells drilled by GREP
P	Piezometers drilled by GREP
F, D,L,X,U	Water wells drilled by DMR

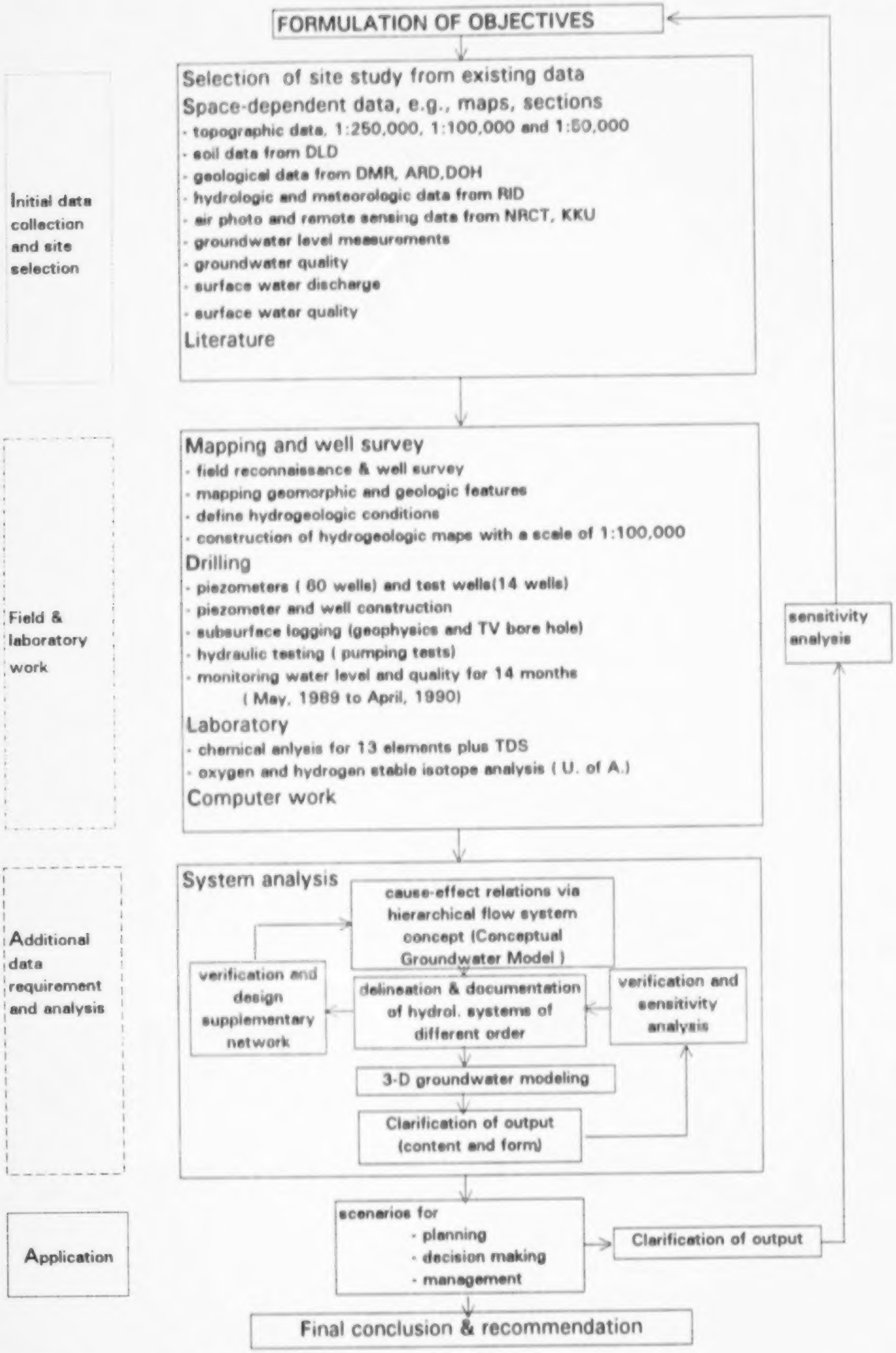

FORMULATION OF OBJECTIVES
Initial data collection and site selection
Selection of site study from existing data
Space-dependent data, e.g., maps, sections
- topographic data, 1:250,000, 1:100,000 and 1:50,000
- soil data from DLD
- geological data from DMR, ARD,DOH
- hydrologic and meteorologic data from RID
- air photo and remote sensing data from NRCT, KKU
- groundwater level measurements
- groundwater quality
- surface water discharge
- surface water quality
Literature
Field & laboratory work
Mapping and well survey
- field reconnaissance & well survey
- mapping geomorphic and geologic features
- define hydrogeologic conditions
- construction of hydrogeologic maps with a scale of 1:100,000
Drilling
- piezometers (60 wells) and test wells(14 wells)
- piezometer and well construction
- subsurface logging (geophysics and TV bore hole)
- hydraulic testing (pumping tests)
- monitoring water level and quality for 14 months
(May, 1989 to April, 1990)
Laboratory
- chemical anlysis for 13 elements plus TDS
- oxygen and hydrogen stable isotope analysis (U. of A.)
Computer work
sensitivity analysis
Additional data requirement and analysis
System analysis
cause-effect relations via hierarchical flow system concept (Conceptual Groundwater Model)
verification and design supplementary network
delineation & documentation of hydrol. systems of different order
verification and sensitivity analysis
3-D groundwater modeling
Clarification of output (content and form)
Application
scenarios for
- planning
- decision making
- management
Clarification of output
Final conclusion & recommendation

Figure 1.2 Flowchart of the application of hydrogeologic system analysis in the Khon Kaen Drainage Basin

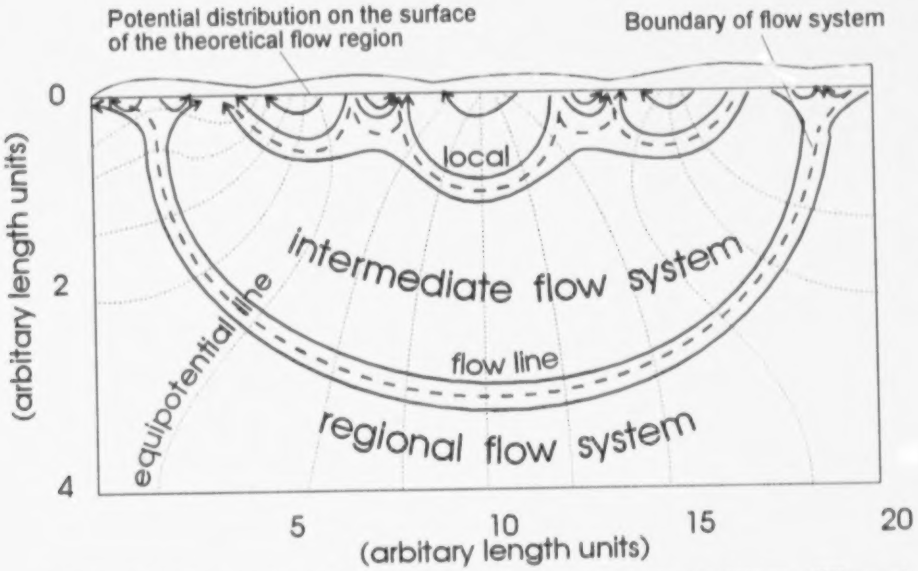

Potential distribution on the surface
of the theoretical flow region
Boundary of flow system
0
2
4
(arbitary length units)
local
intermediate flow system
equipotential line
flow line
regional flow system
5
10
15
20
(arbitary length units)

Figure 2.1 Theoretical flow pattern and boundaries between different flow systems (modified from Tóth, 1963)

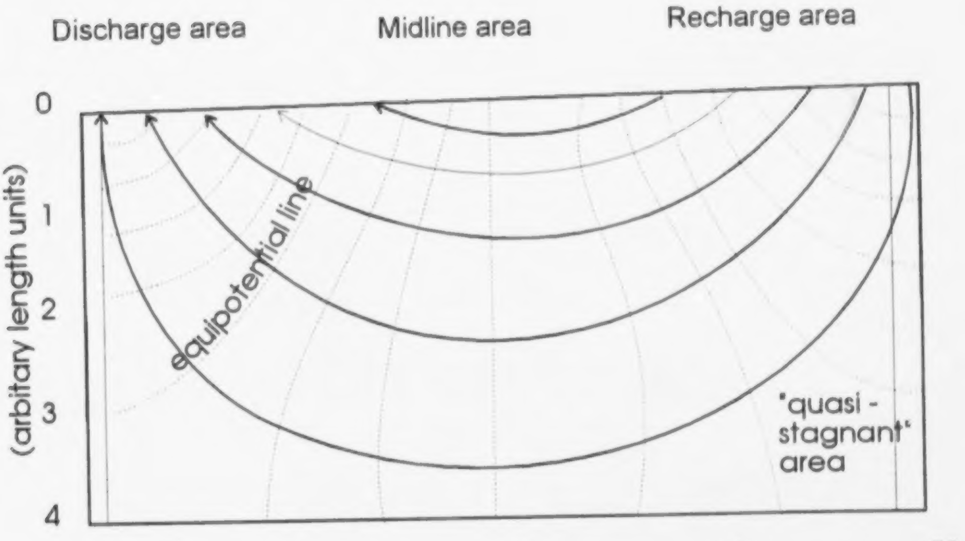

Discharge area
Midline area
Recharge area
0
1
2
3
4
(arbitary length units)
equipotential line
"quasi - stagnant" area
0
5
10
15
20

Figure 2.2 Distribution of recharge and discharge areas (modified from Tóth, 1962)

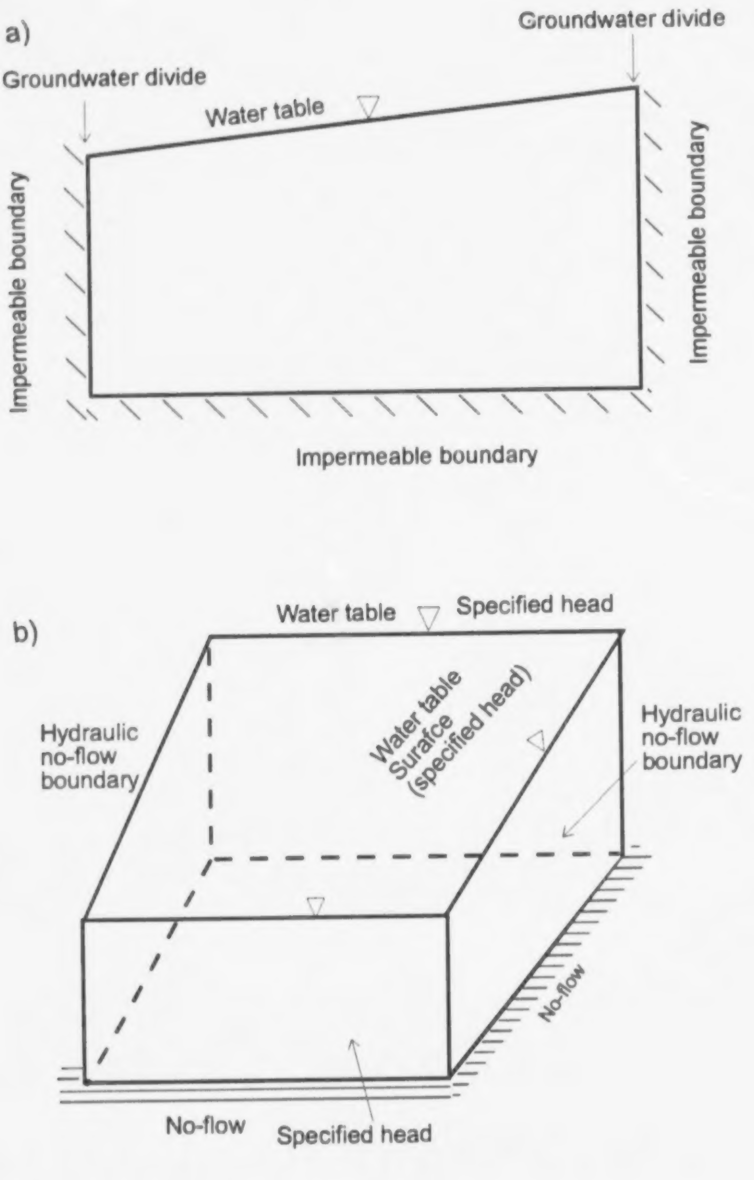

a)
Groundwater divide
Groundwater divide
Water table
Impermeable boundary
Impermeable boundary
Impermeable boundary
b)
Water table
Specified head
Water table
Surafce
(specified head)
Hydraulic
no-flow
boundary
Hydraulic
no-flow
boundary
No-flow
No-flow
Specified head

Figure 2.3 Typical boundaries in regional flow problems
a) Two-dimesional problem in profile view
b) Three-dimesional problem domain
(modified from Anderson and Woessner, 1992)

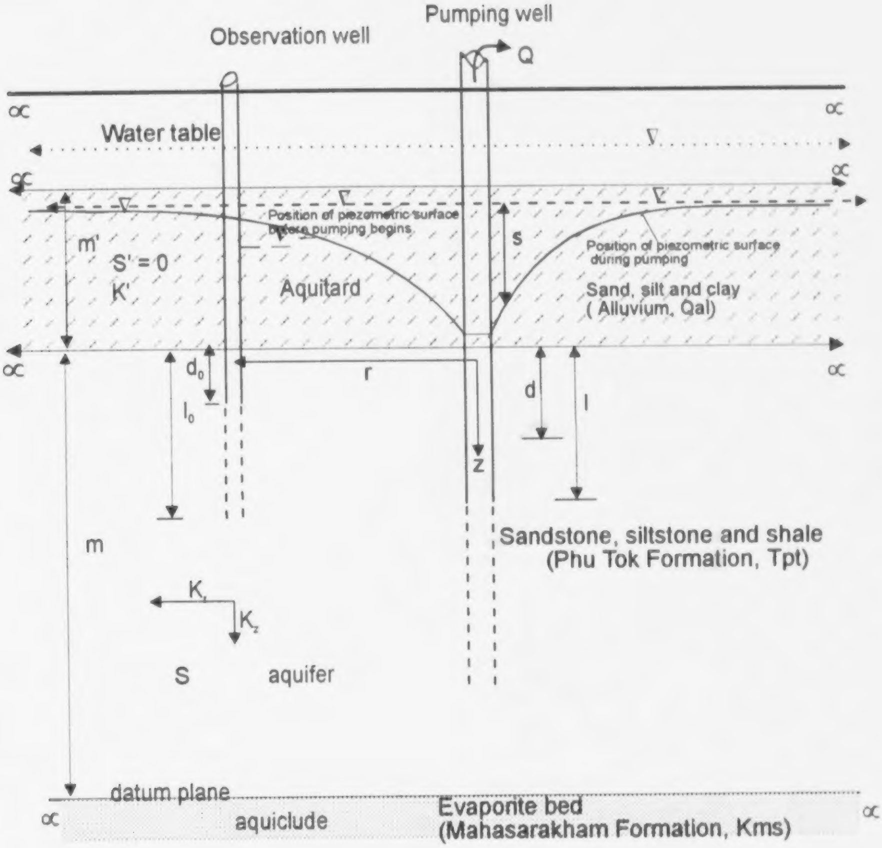

Pumping well
Observation well
Q
∝
Water table
Position of piezometric surface before pumping begins
Position of piezometric surface during pumping
m'
S' = 0
K'
Aquitard
s
Sand, silt and clay
(Alluvium, Qal)
d₀
r
d
l
l₀
z
Sandstone, siltstone and shale
(Phu Tok Formation, Tpt)
m
Kr
Kz
S
aquifer
datum plane
aquiclude
Evaporite bed
(Mahasarakham Formation, Kms)

Figure 2.4 Conceptual model for Transient, leaky, partial penetration and anisotropic aquifer (modified from Dawson and Istok, 1991)

d = distance from the static water table to the top of the pumping well screen, L
d_0 = distance from the static water table to the top of the observation well screen, L
kr = horizontal hydraulic conductivity of aquifer, LT^{-1}
kz = vertical hydraulic conductivity of aquifer, LT^{-1}
l = distance from the static water table to the bottom of the pumping well screen, L
l_0 = distance from the static water table to the bottom of the observation well screen, L
m = saturated thickness before pumping begins, L
m' = aquitard thickness, L
Q = constant pumping rate, L^3T^{-1}
r = radial distance from the pumping to a point on the cone of depression, L
s = drawdown of piezometric surface during pumping, L
S = aquifer storativity, dimensionless
S' = aquitard storativity, dimensionless
z = vertical distance from the aquifer top (positive z is downward), L

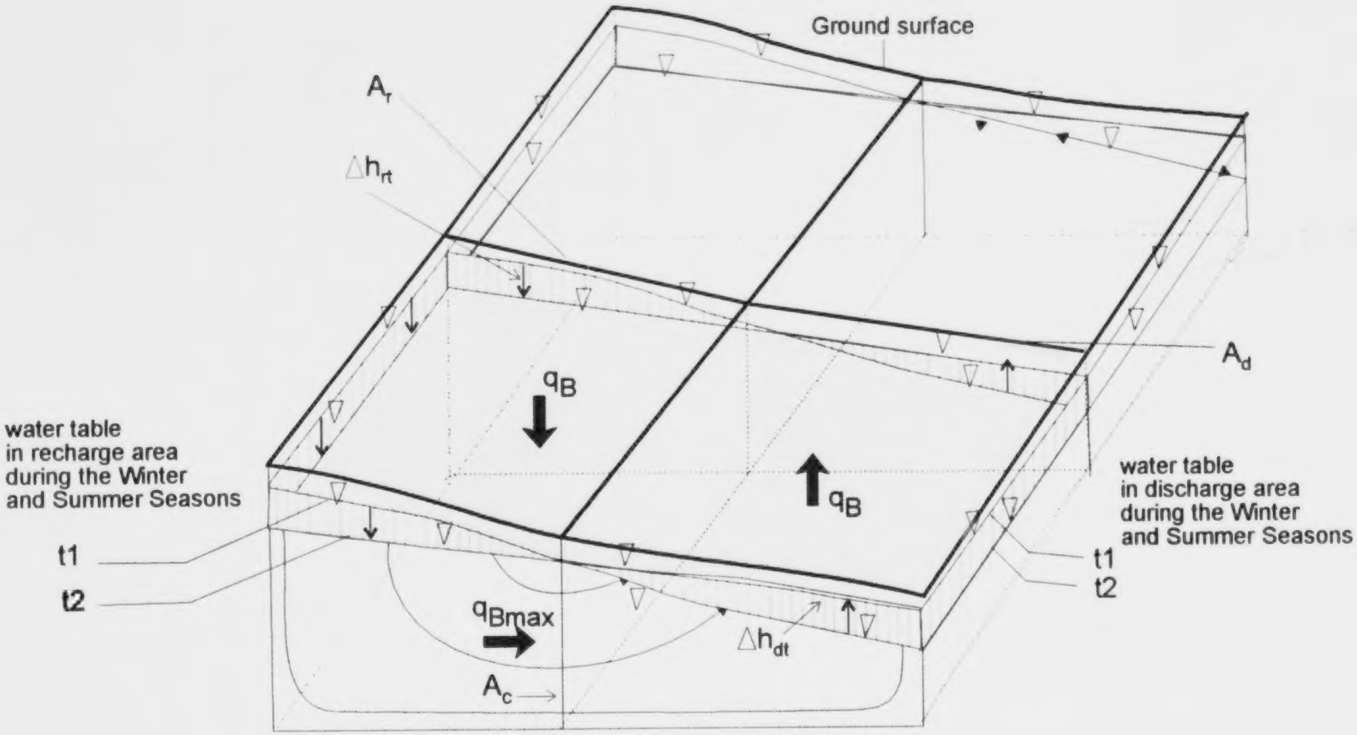

Ground surface
A_r
Δh_rt
A_d
q_B
q_B
water table
in recharge area
during the Winter
and Summer Seasons
t1
t2
water table
in discharge area
during the Winter
and Summer Seasons
t1
t2
q_Bmax
Δh_dt
A_c

Figure 2.5 Diagram illustration of typical groundwater flow system in the Khon Kaen Drainage Basin during the Winter to Summer Seasons (the least rainfall period) (modified from Tóth, 1982)

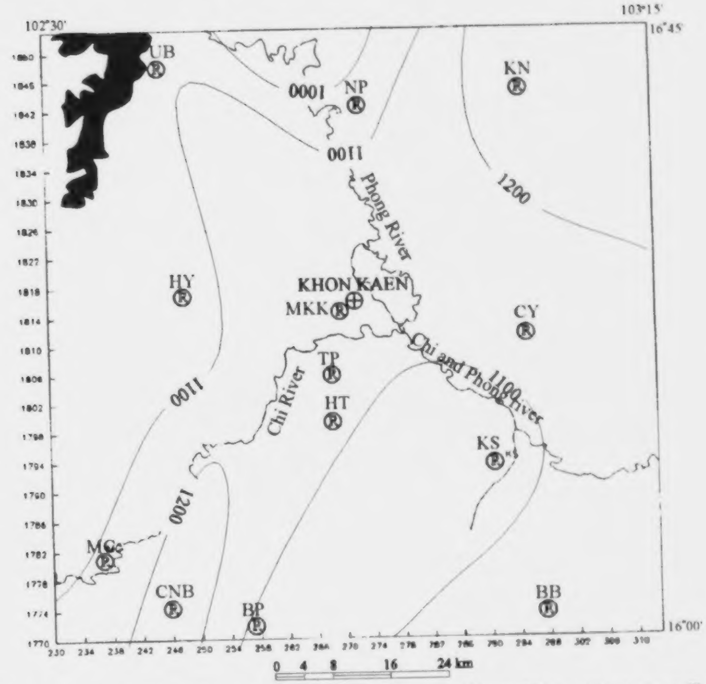

102°30'
103°15'
16°45'
16°00'
UB
NP
KN
HY
KHON KAEN
MKK
CY
TP
HT
KS
MC
CNB
BP
BB
1000
1100
1200
Phong River
Chi River
Chi and Phong River
0 4 8 16 24 km

Figure 3.1a Annual rainfall (mm) distribution in the Khon Kaen Drainage Basin (after RID, 1952 - 1985)

Rainfall station at the Department of Royal Irrigation, Khon Kaen

Contur interval =100 mm

Ⓡ BB = BORABU
BP = BAN PHAI
CNB = CHONNABOT
CY = CHIANG YAN
HT = HUAI TOEI
HY = HUAI YAI
KM = KOK MUANG
KN = KRANUAN
KS = KOSUM PHISAI
MC = MANCHA
MKK = MUANG,KHON KAEN
NP = NAM PHONG
TP = THA PHRA
UB = UBONRAT

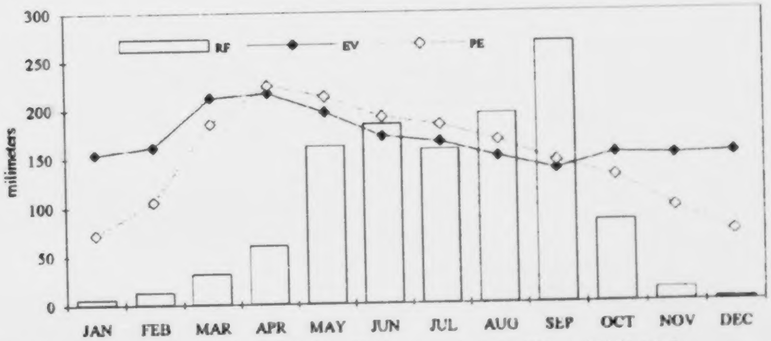


Figure 3.1b Average mothly rainfall (RF), pan evaporation (EV) and potential evapotranspiration (PE) in the Khon Kaen Drainage Basin (after RID, 1952 - 1985)

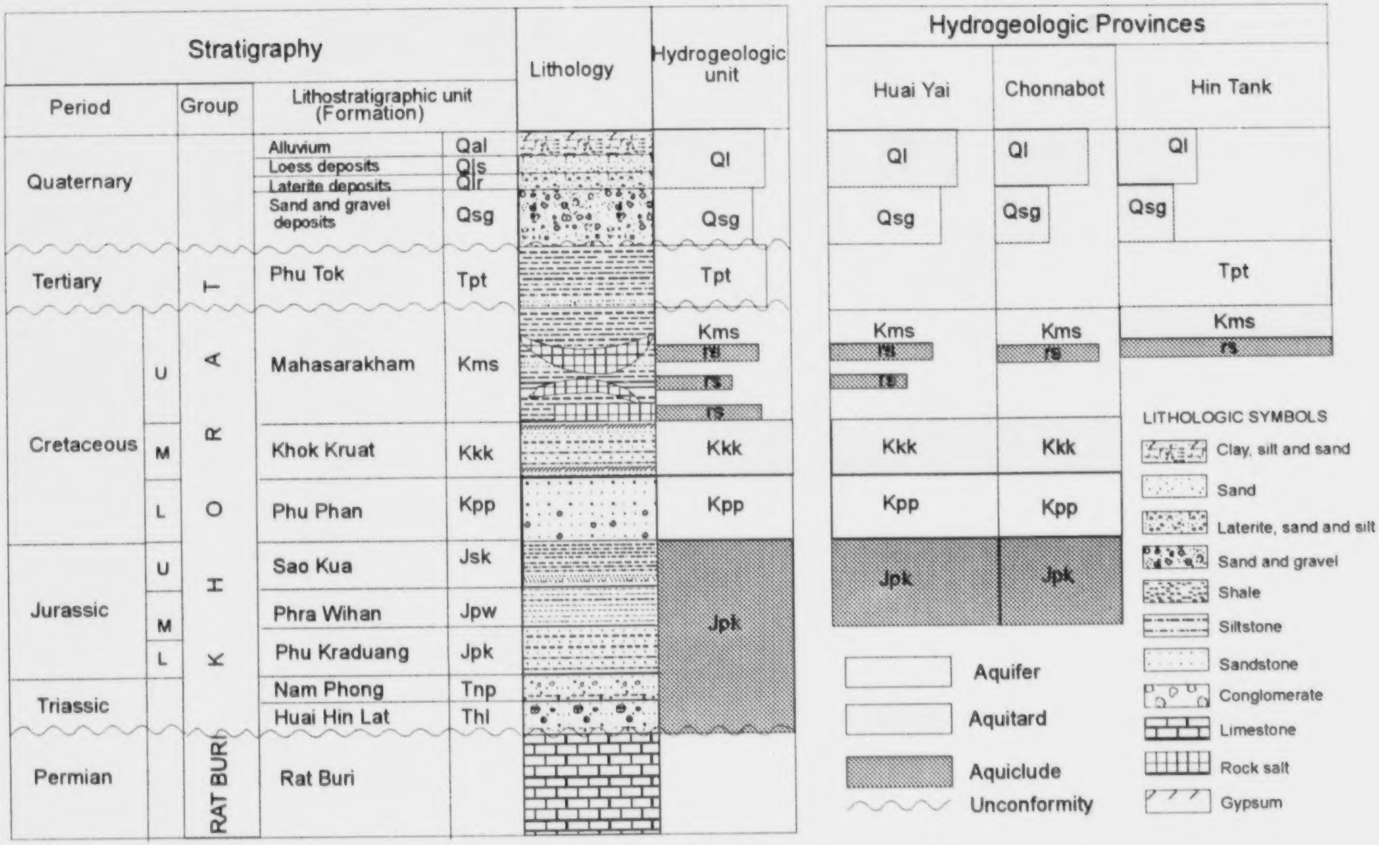

Stratigraphy
Period
Group
Lithostratigraphic unit (Formation)
Lithology
Hydrogeologic unit
Quaternary
Alluvium
Qal
Loess deposits
Qls
Laterite deposits
Qlr
Sand and gravel deposits
Qsg
Ql
Tertiary
Phu Tok
Tpt
Cretaceous
U
M
L
Mahasarakham
Kms
rs
Khok Kruat
Kkk
Phu Phan
Kpp
Jurassic
Sao Kua
Jsk
Phra Wihan
Jpw
Phu Kraduang
Jpk
Triassic
Nam Phong
Tnp
Huai Hin Lat
Thl
Permian
Rat Buri
KHORAT
RAT BURI
Hydrogeologic Provinces
Huai Yai
Chonnabot
Hin Tank
Aquifer
Aquitard
Aquiclude
Unconformity
LITHOLOGIC SYMBOLS
Clay, silt and sand
Sand
Laterite, sand and silt
Sand and gravel
Shale
Siltstone
Sandstone
Conglomerate
Limestone
Rock salt
Gypsum

Figure 3.2 Srtratigraphy and lithology of hydrogeologic units in the Khon Kaen Drainage Basin, Khon Kaen, Thailand (modified from Chonglakmani and Sattayarak, 1978)

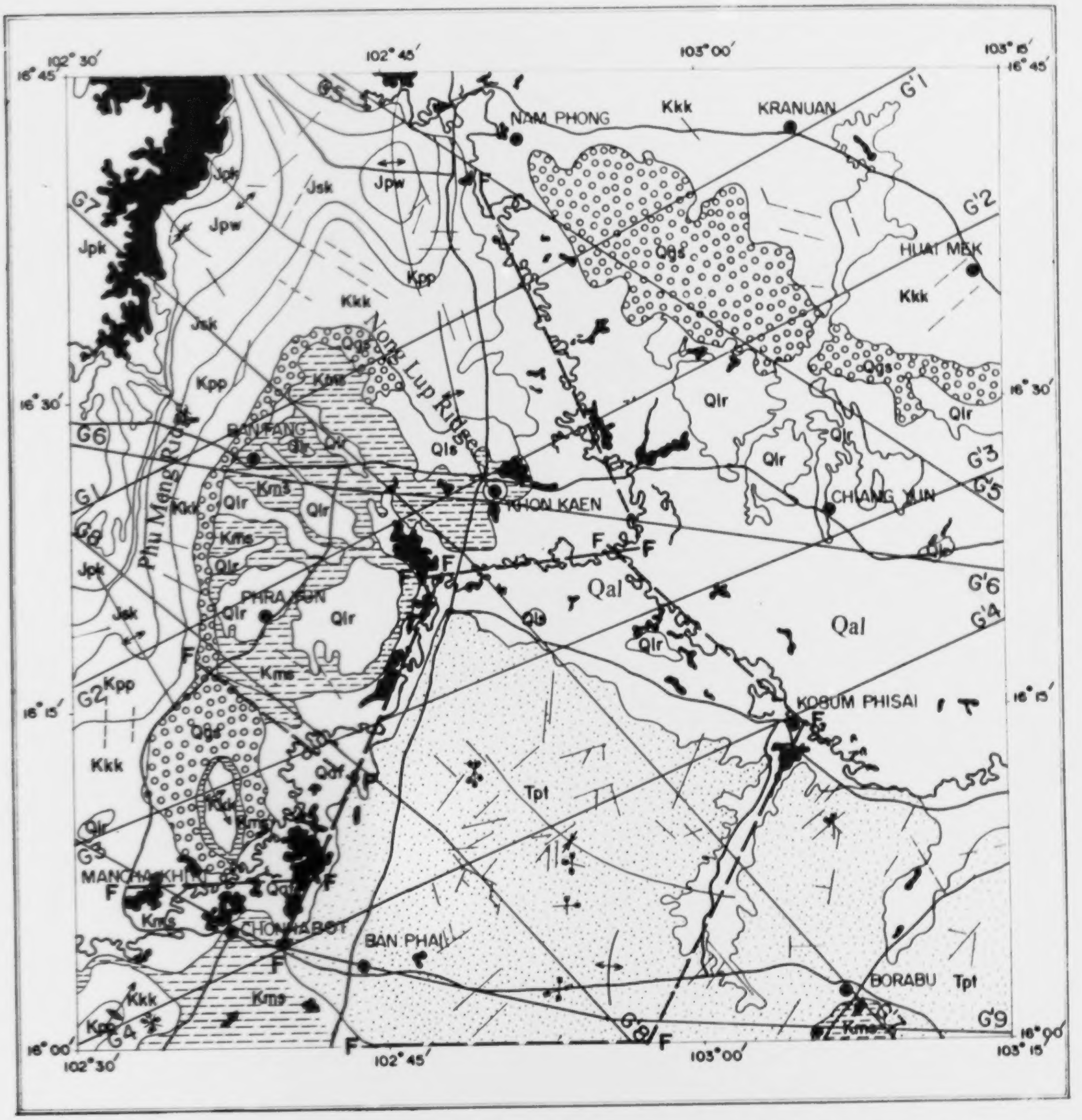

102° 30′
102° 45′
103° 00′
103° 15′
16° 45′
16° 30′
16° 15′
16° 00′
NAM PHONG
KRANUAN
HUAI MEK
KHON KAEN
CHIANG YUN
PHRA YUN
BAN FANG
KOSUM PHISAI
MANCHA KHIRI
CHONNABOT
BAN PHAI
BORABU
Phu Meng Ridge
Nong Lup Ridge
G1
G'1
G2
G'2
G3
G'3
G4
G'4
G5
G'5
G6
G'6
G7
G8
G9
G'9
Qal
Qls
Qlr
Qsg
Tpt
Kms
Kkk
Kpp
Jsk
Jpw
Jpk
F

Figure 3.3 Geologic Map of the Khon Kaen Drainage Basin, Northeast Thailand

(Modified from Hokjaroen, 1986)

Explanation

Qal	Alluvium
Qls	Loess Deposit
Qlr	Laterite
Qsg	Sand and gravel
Tpt	Phu Tok Formation
Kms	Mahasarakham Formation
Kkk	Khok Krua Formation
Kpp	Phu Phan Formation
Jsk	Sao Kua Formation
Jpw	Phra Wihan Formation
Jpk	Phu Kradung Formation

Geologic boundary

Approximate geologic boundary

Unconformity

F Fault

Joint or fracture

Vertical joint

Anticline

Syncline

River

Reservoir and pond

G1 — G'1 Line of Geologic X- section

Road

● Amphoe (District)

◉ Khon Kaen Province

N

5 0 5 10 15 20 Km

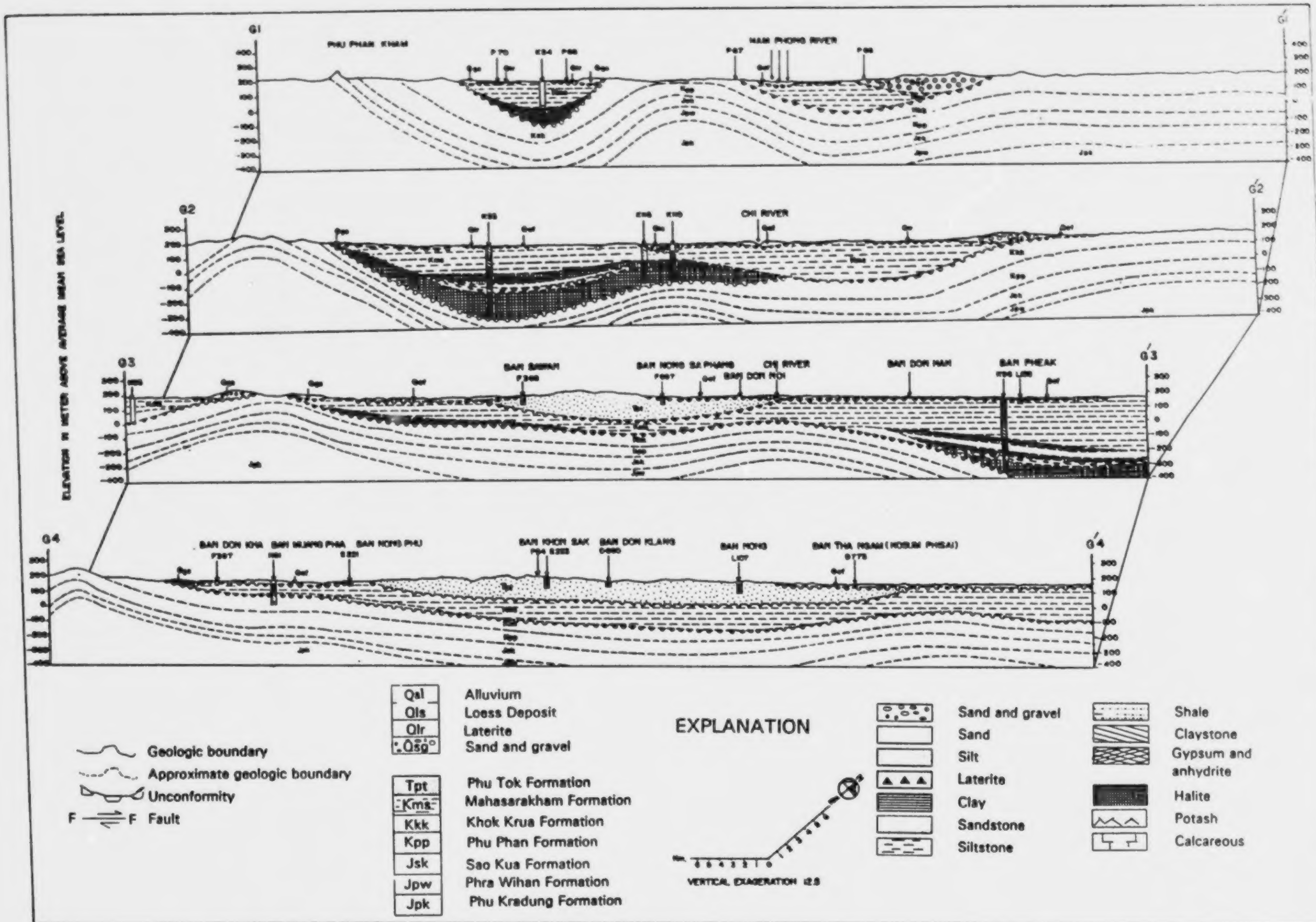

G1
PHU PHAN KHAM
P70
K34
P66
P67
NAM PHONG RIVER
P68
G1'
G2
K55
CHI RIVER
G2'
ELEVATION IN METER ABOVE AVERAGE MEAN SEA LEVEL
G3
BAN SAWAN
F300
BAN NONG SA PHANG
BAN DON NOI
CHI RIVER
BAN DON HAN
BAN PHEAK
G3'
G4
BAN DON KHA
F307
BAN MUANG PHA
BAN NONG PHU
BAN KHON SAK
BAN DON KLANG
BAN NONG
BAN THA NGAM (KOSUM PHISAI)
G4'
Geologic boundary
Approximate geologic boundary
Unconformity
F F Fault
Qal Alluvium
Qls Loess Deposit
Qlr Laterite
Qsg Sand and gravel
Tpt Phu Tok Formation
Kms Mahasarakham Formation
Kkk Khok Krua Formation
Kpp Phu Phan Formation
Jsk Sao Kua Formation
Jpw Phra Wihan Formation
Jpk Phu Kradung Formation
EXPLANATION
VERTICAL EXAGERATION 12.5
Sand and gravel
Sand
Silt
Laterite
Clay
Sandstone
Siltstone
Shale
Claystone
Gypsum and anhydrite
Halite
Potash
Calcareous

Figure 3.4a Three-dimensional Geology of the Khon Kaen Drainage Basin

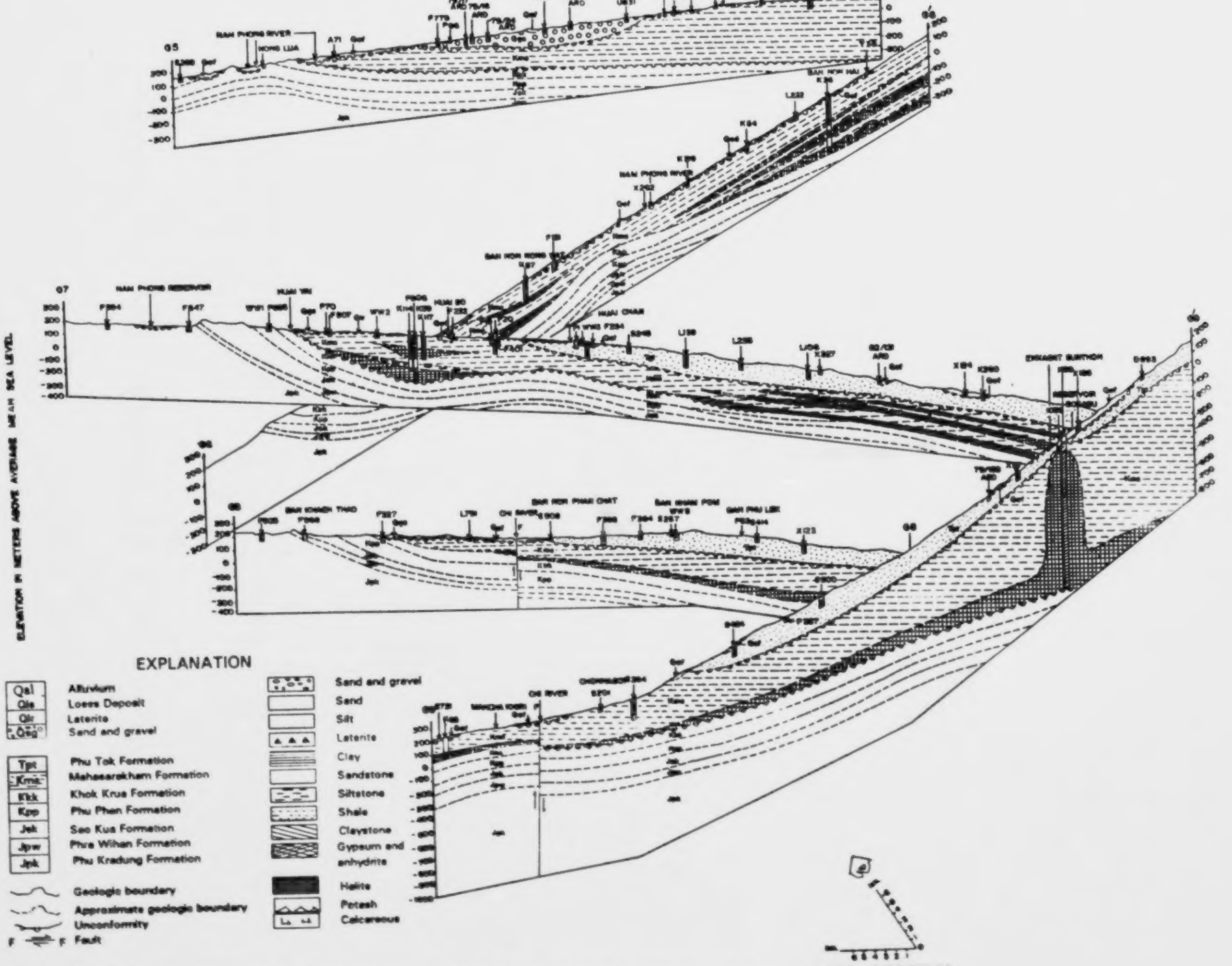

ELEVATION IN METERS ABOVE AVERAGE MEAN SEA LEVEL
G5
G5'
G6
G6'
G7
G8
NAM PHONG RIVER
NONG LUA
HUAI SAI BAT
HUAI SIDA
BAN NON HAI
NAM PHONG RIVER
NAM PHONG RESERVOIR
HUAI YAI
HUAI CHAN
CHI RIVER
BAN PHU LEK
CHI RIVER
EXPLANATION
Qal Alluvium
Qls Loess Deposit
Qlr Laterite
Qsg Sand and gravel
Tpt Phu Tok Formation
Kms Mahasarakham Formation
Kkk Khok Krua Formation
Kpp Phu Phan Formation
Jsk Sao Kua Formation
Jpw Phra Wihan Formation
Jpk Phu Kradung Formation
Geologic boundary
Approximate geologic boundary
Unconformity
F F Fault
Sand and gravel
Sand
Silt
Laterite
Clay
Sandstone
Siltstone
Shale
Claystone
Gypsum and anhydrite
Halite
Potash
Calcareous
VERTICAL EXAGGERATION 12.5

Figure3.4bThree-dimensional Geology of the Khon Kaen Drainage Basin

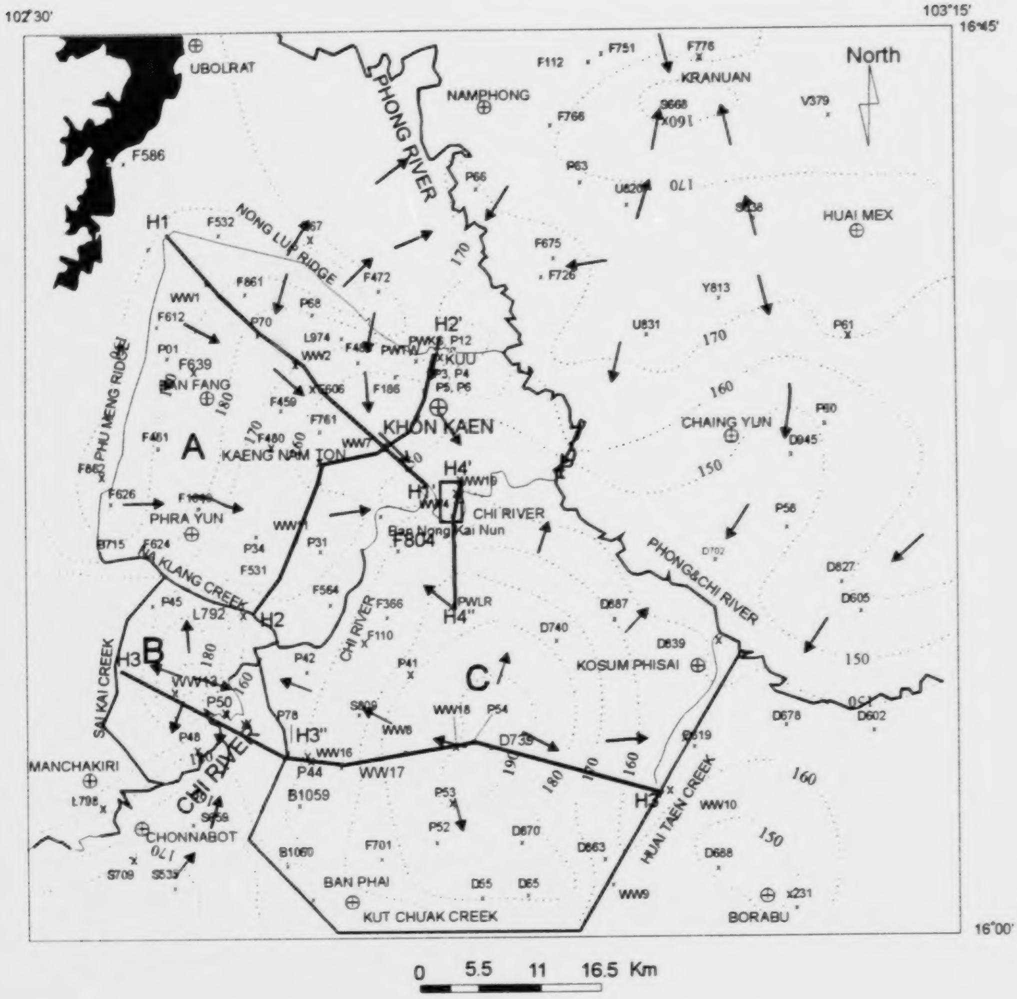

102°30'
103°15'
16°45'
16°00'
North
UBOLRAT
NAMPHONG
PHONG RIVER
KRANUAN
HUAI MEX
NONG LUP RIDGE
PHU MENG RIDGE
BAN FANG
KHON KAEN
KAENG NAM TON
PHRA YUN
CHI RIVER
Ban Nong Kai Nun
CHAING YUN
PHONG&CHI RIVER
KOSUM PHISAI
HUAI KLANG CREEK
SAI KAI CREEK
MANCHAKIRI
CHONNABOT
BAN PHAI
KUT CHUAK CREEK
HUAI TAEN CREEK
BORABU
A
B
C
H1
H1'
H2
H2'
H3
H3'
H3"
H4'
H4"
150
160
170
180
190
0
5.5
11
16.5 Km

Figure 3.5 Distribution of hydraulic potential and regional groundwater flow in the Khon Kaen Drainage Basin

Hydrogeologic Provinces
A Huai Yai
B Chonnabot
C Hin Tank

□ Ban Nong Khai Nun
⊕ Amphoe or district

River and stream
H1———H1' Line of hydrogeologic profile
WW, PW Water wells drilled by GREP
P Piezometer drilled by GREP
F, D,L,X,U Water wells drilled by DMR
150 Equipotential line
→ Regional groundwater flow

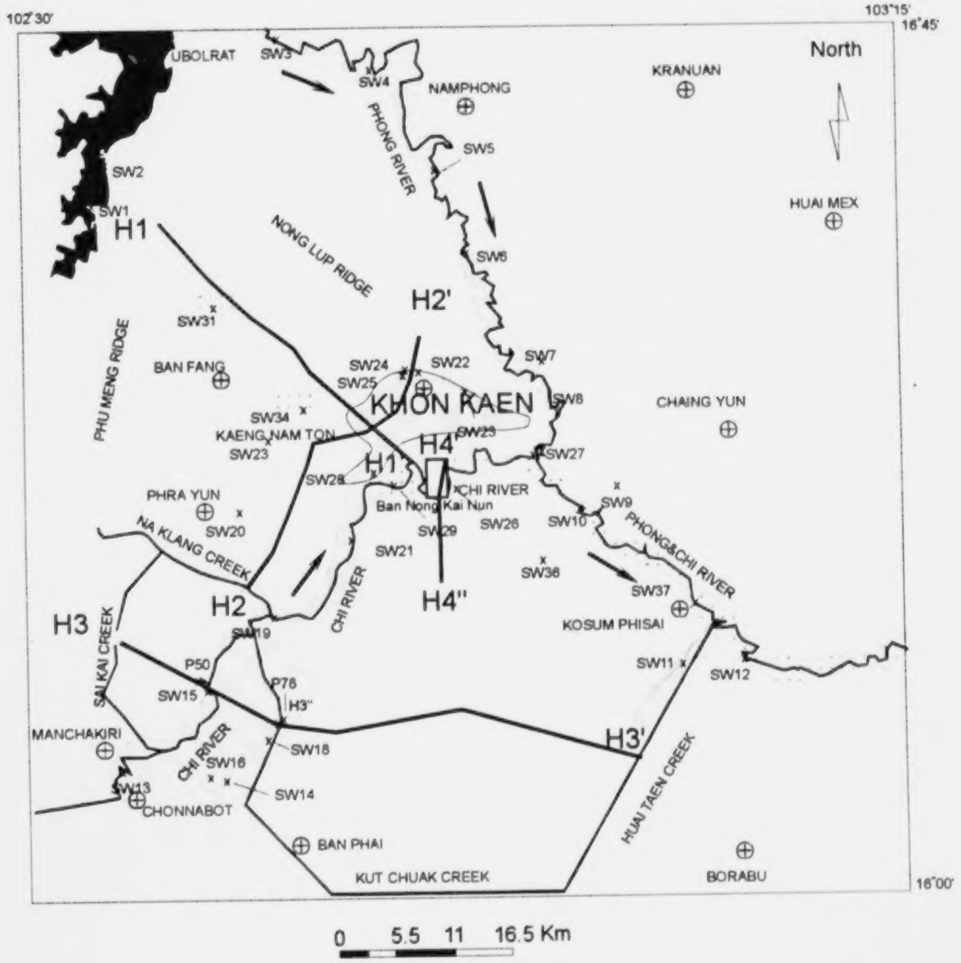
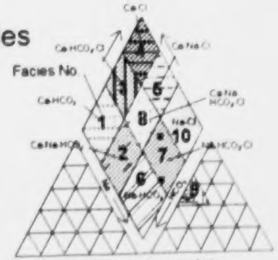

102°30'
103°15'
16°45'
16°00'
North
UBOLRAT
SW3
SW4
NAMPHONG
KRANUAN
PHONG RIVER
SW5
SW2
SW1
H1
HUAI MEX
NONG LUP RIDGE
SW6
H2'
SW31
PHU MENG RIDGE
BAN FANG
SW24
SW25
SW22
SW7
KHON KAEN
SW8
CHAING YUN
SW34
KAENG NAM TON
SW23
SW23
H1''
H4'
SW27
SW28
CHI RIVER
Ban Nong Kai Nun
PHRA YUN
SW20
SW29
SW26
SW10
SW9
NA KLANG CREEK
SW21
PHONG&CHI RIVER
SW36
CHI RIVER
H4''
SW37
H3
H2
KOSUM PHISAI
SAI KAI CREEK
SW19
P50
P78
SW11
SW12
SW15
H3''
MANCHAKIRI
CHI RIVER
H3'
SW18
SW16
SW14
HUAI TAEN CREEK
SW13
CHONNABOT
BAN PHAI
BORABU
KUT CHUAK CREEK
0 5.5 11 16.5 Km

Figure 3.6 Hydrochemical facies of surface water in the Khon Kaen Drainage Basin

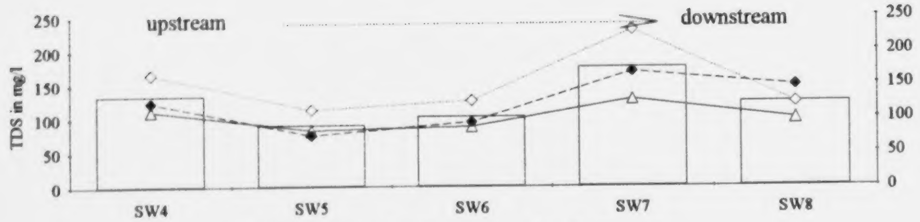
x SW Location of surface water samples

x P50 Piezometers

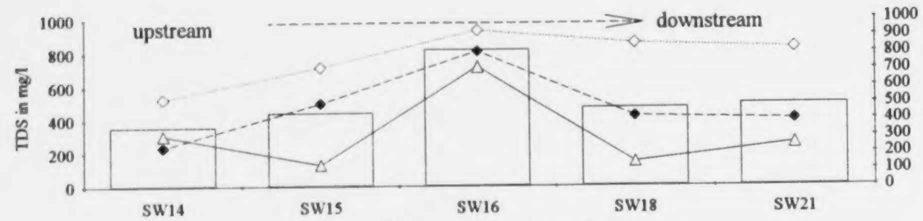
⟶ Surface water flow direction


CaCl
CaHCO₃,Cl
CaNaCl
Facies No.
CaHCO₃
CaNa HCO₃,Cl
NaCl
CaNaHCO₃
NaHCO₃,Cl
1
2
3
4
5
6
7
8
9
10

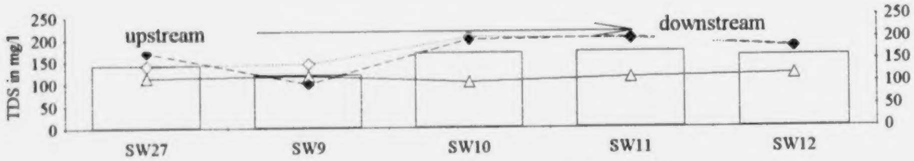
Hydrochemical facies classification After Galloway and Kaiser (1980)



a) TDS concentration of surface water along the Phong River



b) TDS concentration of surface water along the Chi River



c) TDS concentration of surface water along the Phong and Chi Rivers

C

Figure 3.7 Seasonal variation in total dissolved solids of surface water along the major streams in the Khon Kaen Drainage Basin (ANN = annual average, SS = Summer Season, RS = Rainy Season and WS = Winter Season)

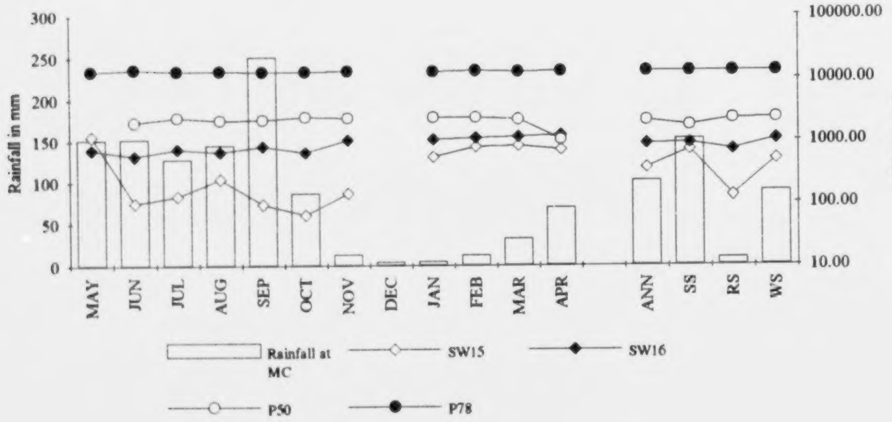


Figure 3.8 Monthly variations in total dissolved solids of selected surface water (SW15 and SW16) in the Khon Kaen Drainage Basin and groundwater samples (P50 and P78)

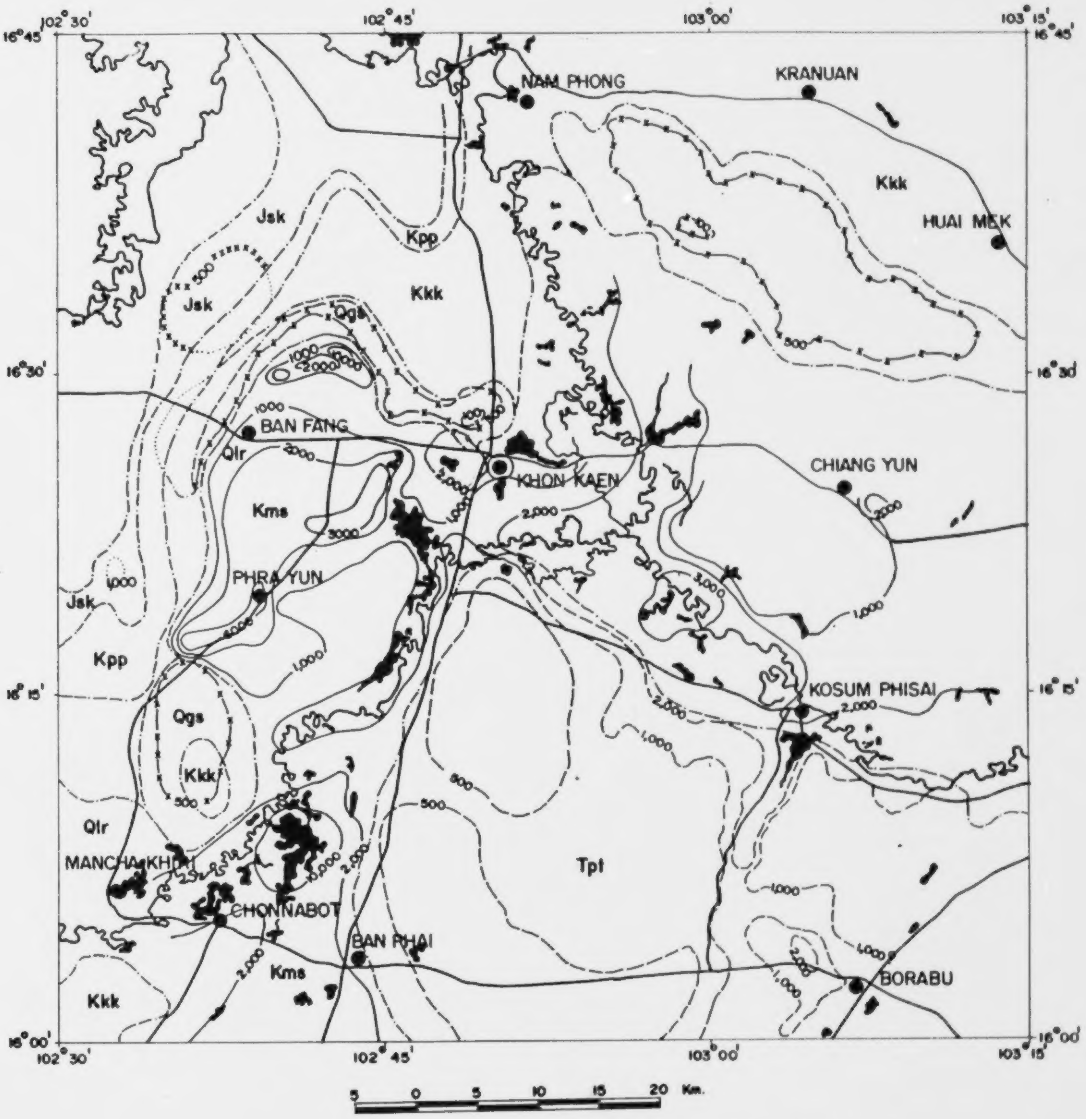

102°30'
102°45'
103°00'
103°15'
16°45'
16°30'
16°15'
16°00'
NAM PHONG
KRANUAN
Kkk
HUAI MEK
Jsk
Kpp
Kkk
Jsk
Qgs
500
1000
2000
BAN FANG
Qlr
KHON KAEN
CHIANG YUN
Kms
3000
PHRA YUN
Jsk
Kpp
KOSUM PHISAI
Qgs
Kkk
Qlr
MANCHA KHIRI
CHONNABOT
BAN PHAI
Tpt
BORABU
Kms
Kkk
5 0 5 10 15 20 Km.

Figure 3.9 Distribution of TDS contents in aquifers in the Khon Kaen Drainage Basin

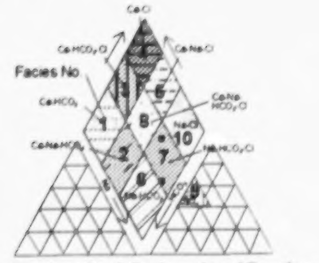
-x-x-100-x-x- TDS contour in sand and gravel deposit (Qsg)

- - - -500- - - - - TDS contour in Phu Tok Fm. (Tpt)

——1000—— TDS contour in Mahasarakham Fm. (Kms)

· · · · -500- · · · · · TDS contour in Phu Phan Fm. (Kpp)

· · — · · — · · Geologic boundary


CaCl
Facies No.
CaHCO3
CaNaHCO3
CaNaCl
NaCl
1
2
3
4
5
6
7
8
9
10

Hydrochemical facies classification
(After Galloway and Kaiser, 1980)

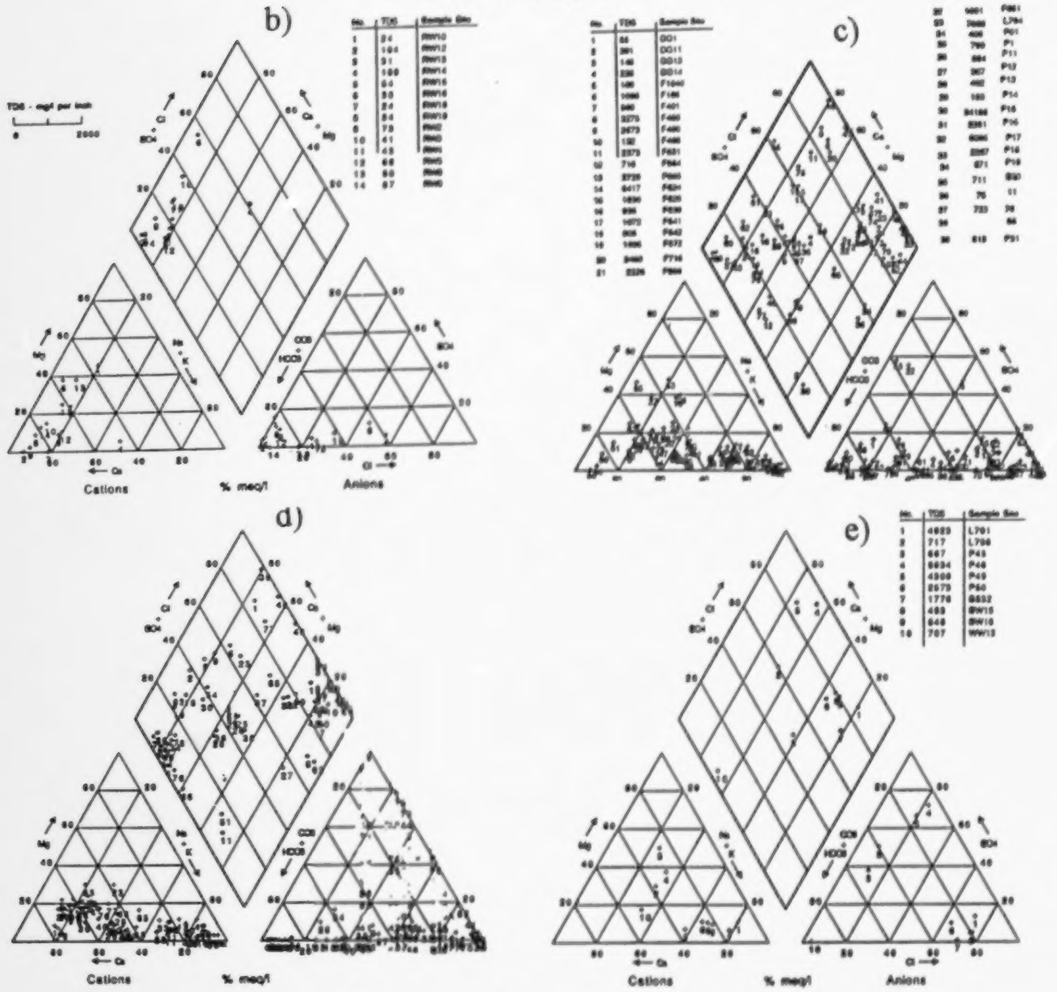


Figure 3.10 Piper's diagram (modified by Galloway and Kaiser, 1980) for water samples in the Khon kaen Drainage Basin

b) Rain water
c) Groundwater in Huai Yai HP
d) Groundwater in Chonnabot HP
e) Groundwater in Hin Tank HP

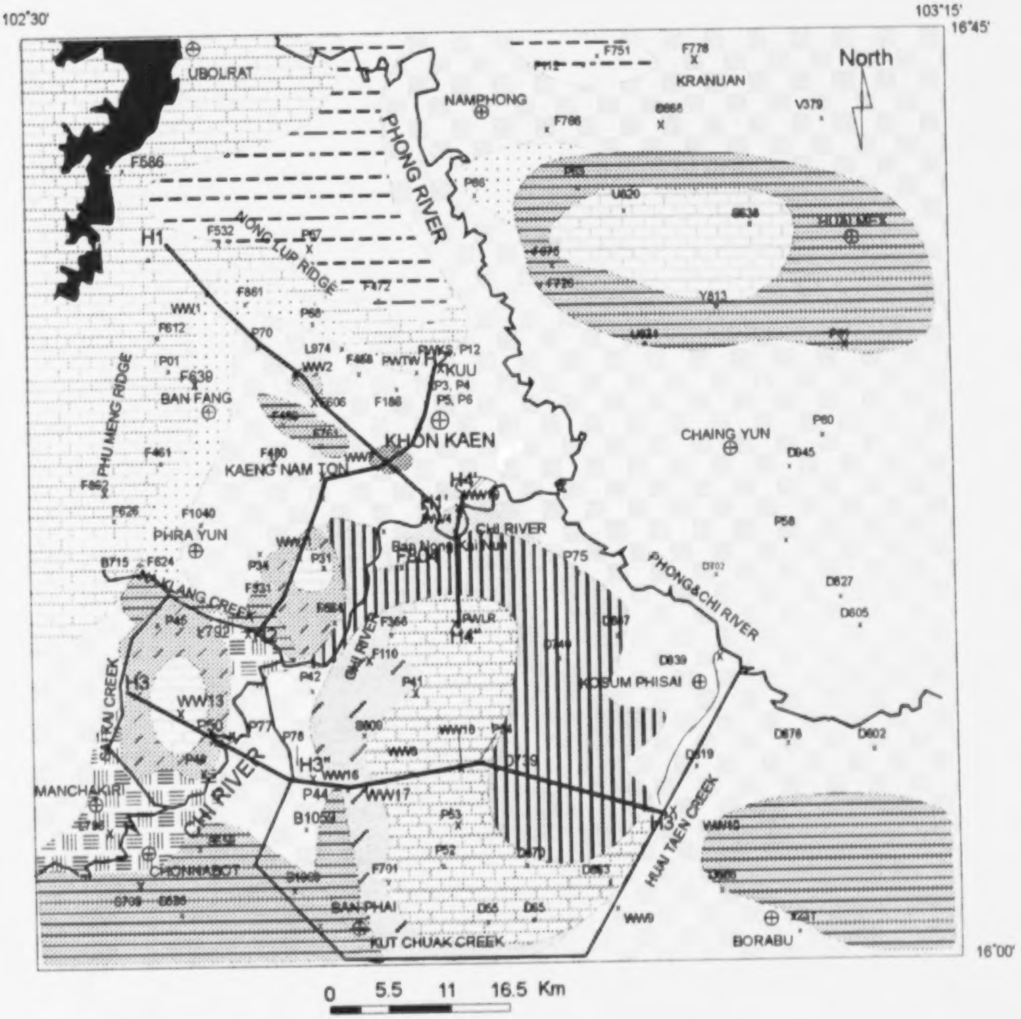
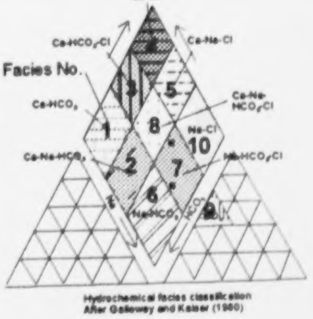

102°30'
103°15'
16°45'
16°00'
North
UBOLRAT
NAMPHONG
KRANUAN
PHONG RIVER
NONG LUP RIDGE
PHU MENG RIDGE
H1
F586
F532
P57
F472
F861
WW1
F612
P70
L974
WW2
F468
PWTW
PWKS, P12
KKUU
P3, P4
P5, P6
P01
F639
BAN FANG
F606
F186
KHON KAEN
F461
F480
KAENG NAM TON
F862
H4'
F626
F1040
PHRA YUN
CHI RIVER
Ban Nong Kai Nun
B715
F624
KLANG CREEK
P34
P31
F531
P45
F792
H2
F366
PWLR
H4''
F110
P42
CHI RIVER
P41
H3
WW13
P50
P77
P76
B600
WW18
P49
WW6
D739
H3''
WW16
MANCHAKIRI
P44
WW17
B1059
P53
H3'
CHI RIVER
P52
D470
CHONNABOT
S709
F701
D653
SAN PHAI
D65
KUT CHUAK CREEK
WW9
BORABU
HUAI TAEN CREEK
KOSUM PHISAI
D839
D819
D876
D602
P75
D747
PHONG&CHI RIVER
D627
D605
P58
CHAING YUN
P60
D845
F751
F778
F786
B868
V379
P66
U620
B638
HUAI ME
F675
F720
Y613
U634
WW15
0
5.5
11
16.5 Km

Figure 3.11 Distribution of hydrochemical facies in the Khon Kaen Drainage Basin

⋯	Stream
●	Lake or reservoir
H3" ___ H3'	Line of hydrogeological profile
WW4	Water wells
P1	Piezometers
SW12	surface water


Ca-Cl
Ca-HCO3-Cl
Ca-Na-Cl
Facies No.
Ca-HCO3
Ca-Na-HCO3-Cl
Na-Cl
Ca-Na-HCO3
Na-HCO3-Cl
Na-HCO3
1
2
3
4
5
6
7
8
9
10

Hydrochemical facies classification After Galloway and Kaiser (1980)

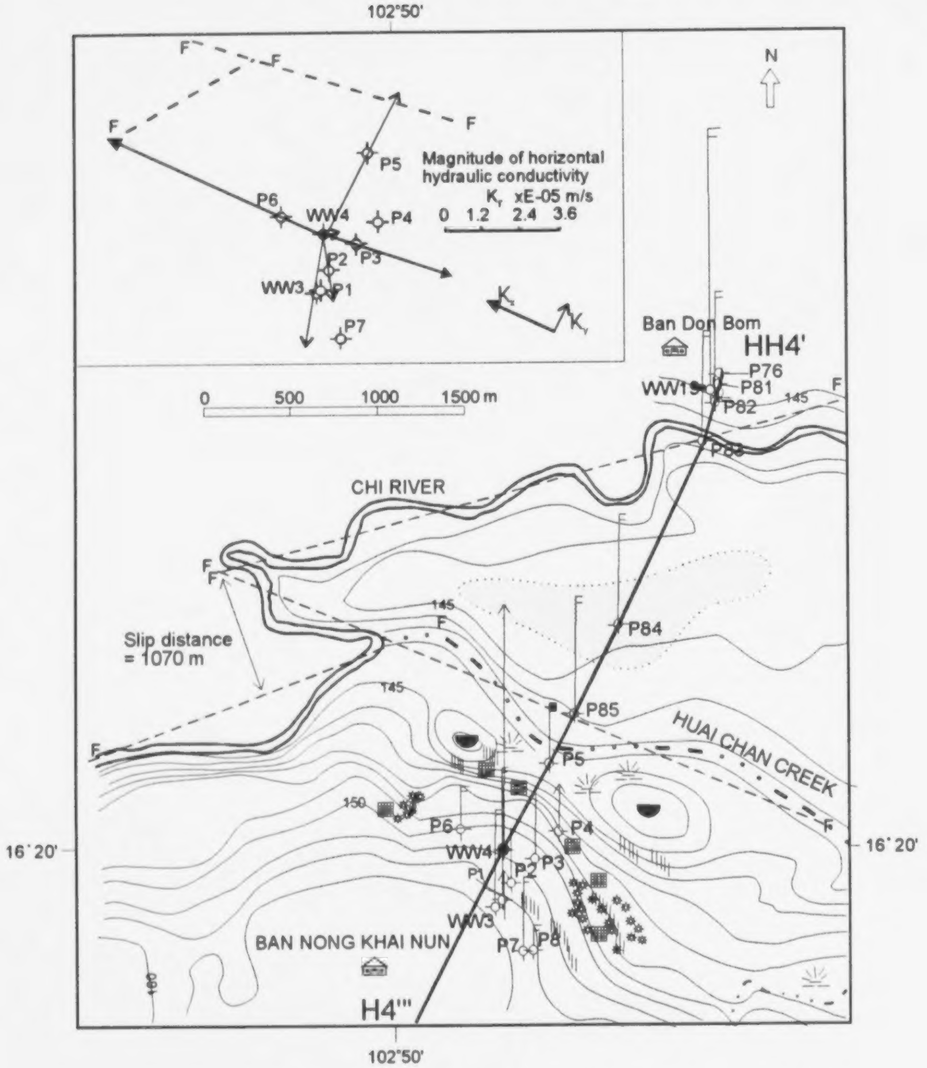

102°50'
F
F
F
F
P5
Magnitude of horizontal
hydraulic conductivity
K_Y xE-05 m/s
0 1.2 2.4 3.6
P6
WW4
P4
P2
P3
WW3
P1
P7
K_X
K_Y
N
Ban Don Bom
HH4'
P76
WW19
P81
P82
145
F
P83
0 500 1000 1500 m
CHI RIVER
F
F
Slip distance
= 1070 m
145
F
P84
145
P85
HUAI CHAN CREEK
P5
F
150
P6
P4
16°20'
WW4
P1
P2
P3
16°20'
WW3
BAN NONG KHAI NUN
P7
P8
160
H4'''
102°50'

Figure 3.12 Hydrogeologic map of Ban Nong Khai Nun, Khon Kaen

TOPOGRAPHY
160 Topographic contour(CI=1 m)
Road
HYDROGRAPHY
Natural pond
Marsh or swamp
River
Stream, intermittent
GROUNDWATER HYDROLOGY
Recharge Discharge Boundary area of recharge and discharge
▨ Area of saline soil
Salt-tolerant plant
Soap holes
Water well, drilled
0 5 10 15 Depth to water Depth of well
0 5 10 Depth of well, water well, and flowing well
F_ _ _F Fault
H4'''___H4' Hydrogeologic profile

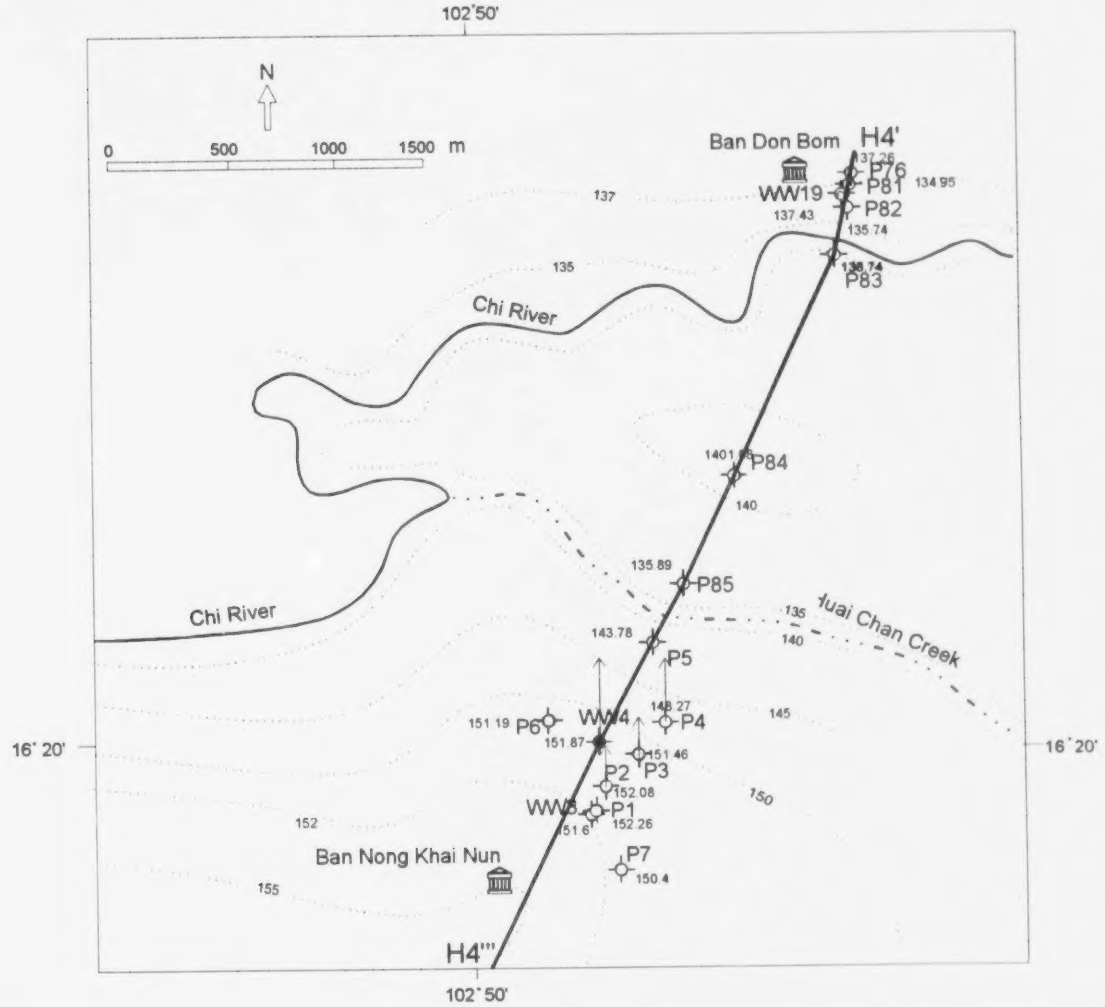

102°50'
N
0
500
1000
1500
m
Ban Don Bom
H4'
137.26
P76
P81
134.95
WW19
P82
137.43
135.74
137
135
136.74
P83
Chi River
1401.68
P84
140
135.89
P85
Chi River
135
Huai Chan Creek
140
143.78
P5
148.27
WW4
151.19
P6
P4
145
16° 20'
151.87
151.46
P2
P3
16° 20'
150
152.08
WW3
P1
152
151.6
152.26
Ban Nong Khai Nun
P7
150.4
155
H4'''
102° 50'

Figure 3.13 Distribution of average hydraulic heads at Ban Nong Khai Nun

⋯ 150	Equipotential line in m above mean sea level
⌖ P7	Piezometer or observation well
↑ ⌖	Flowing well
✦ WW4	Pumped well
H4''' ___ H4'	Hydrogeologic profile

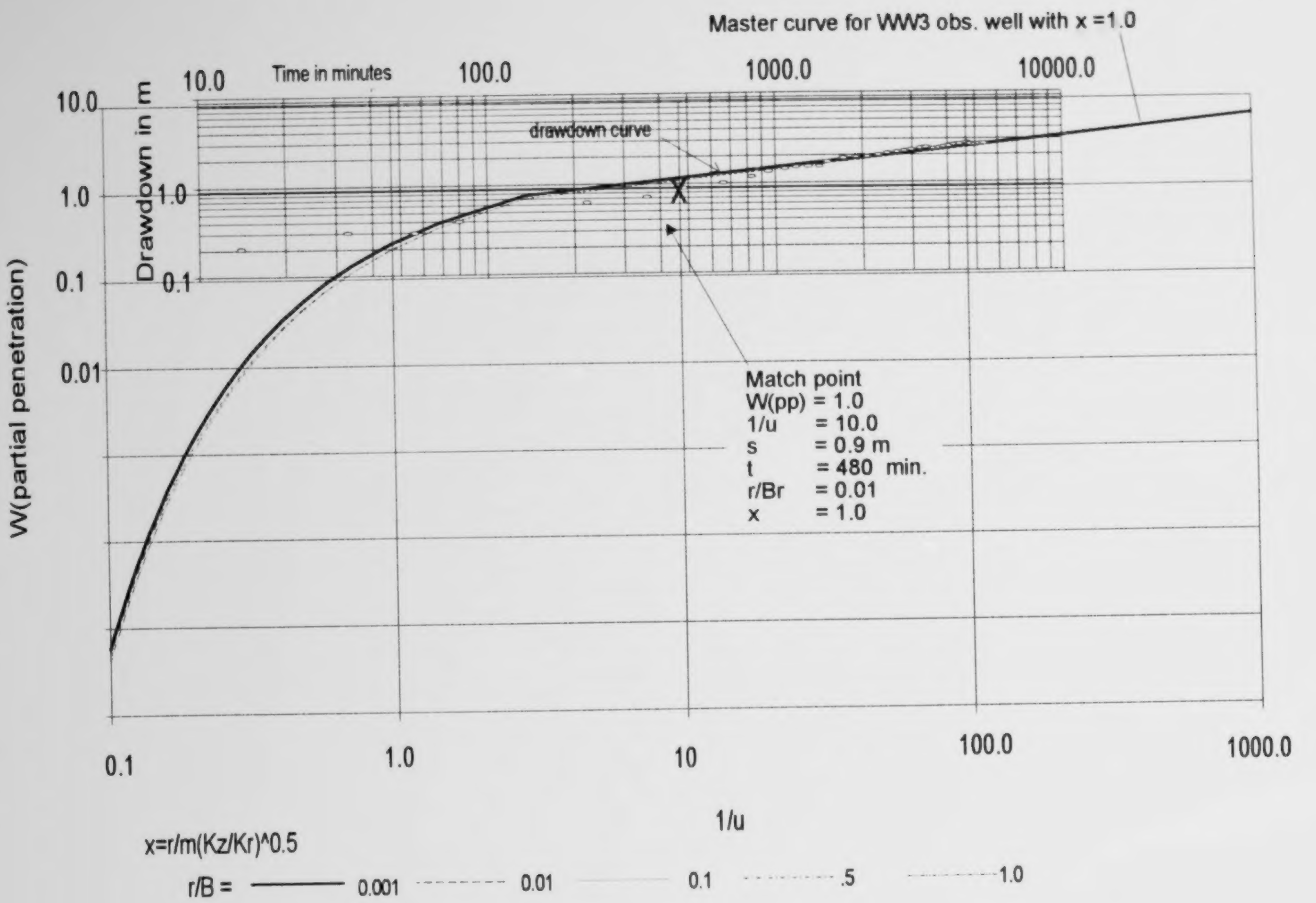


Figure 3.14a Time drawdown curve for WW3 during pump test WW4

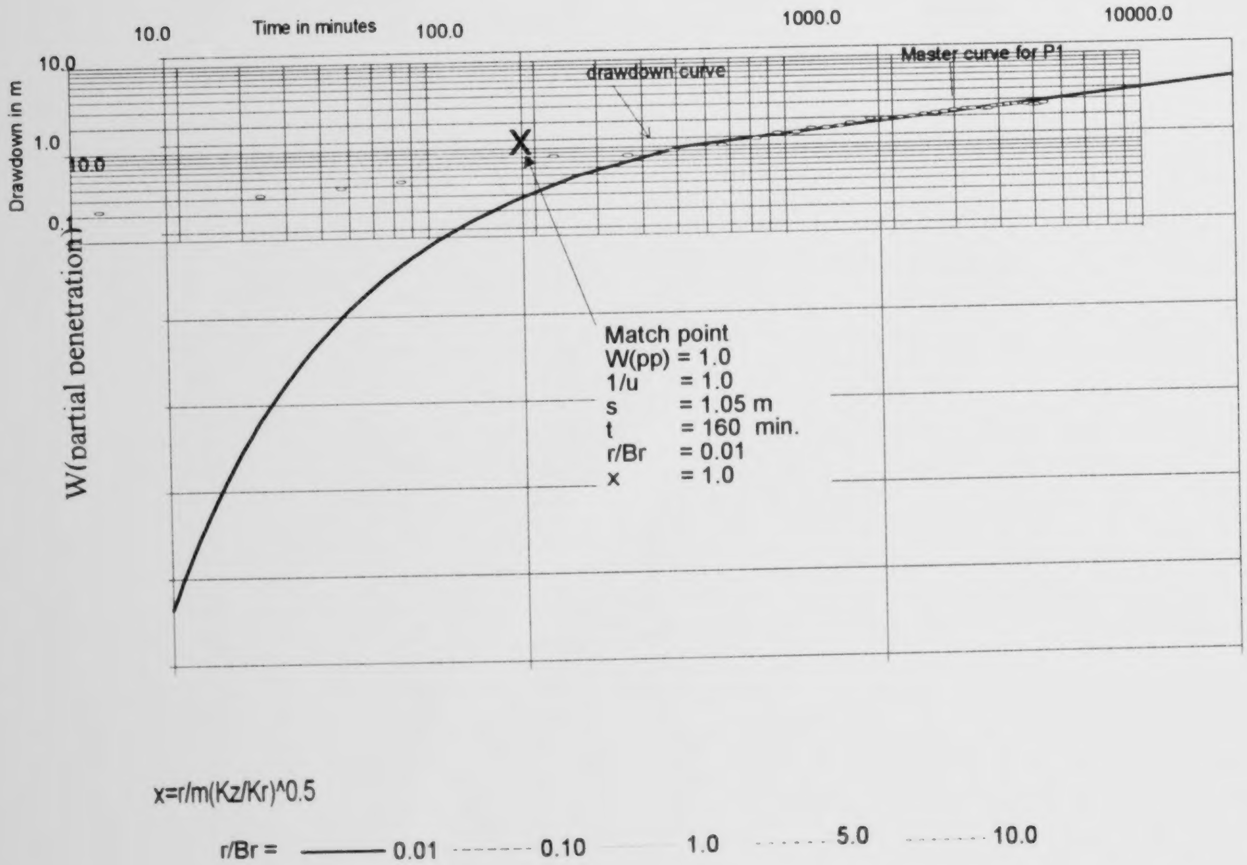


Figure 3.14b Time drawdown curve for P1 during pump test WW4

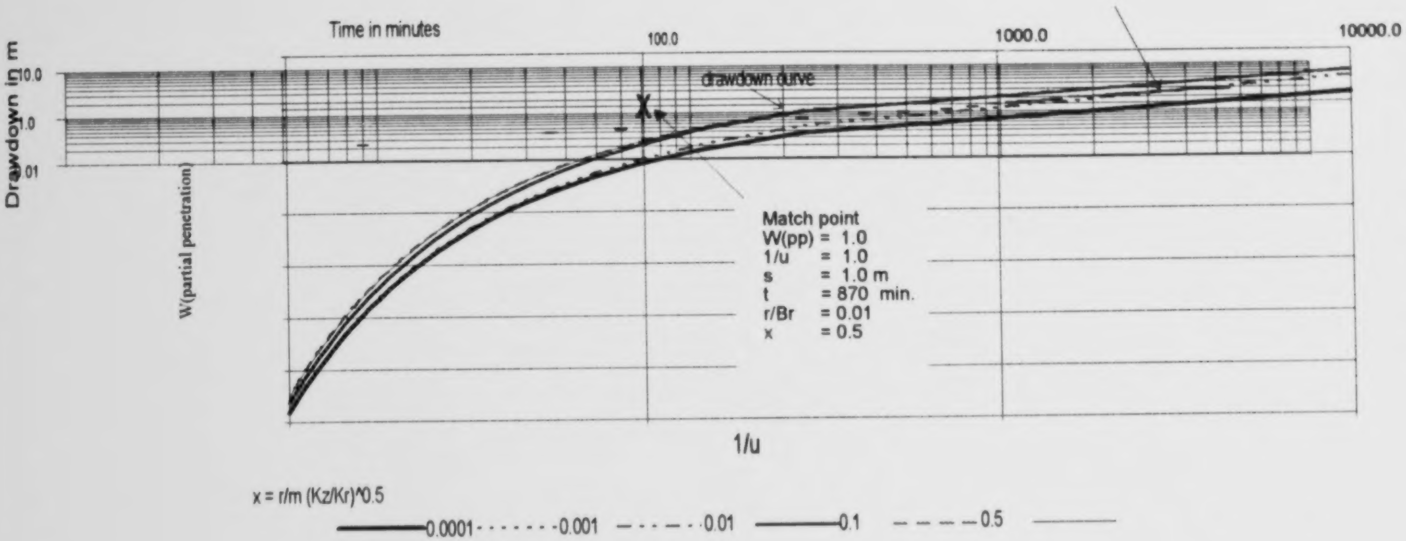


Figure 3.14c Time drawdown curve for P2 during pump test WW4

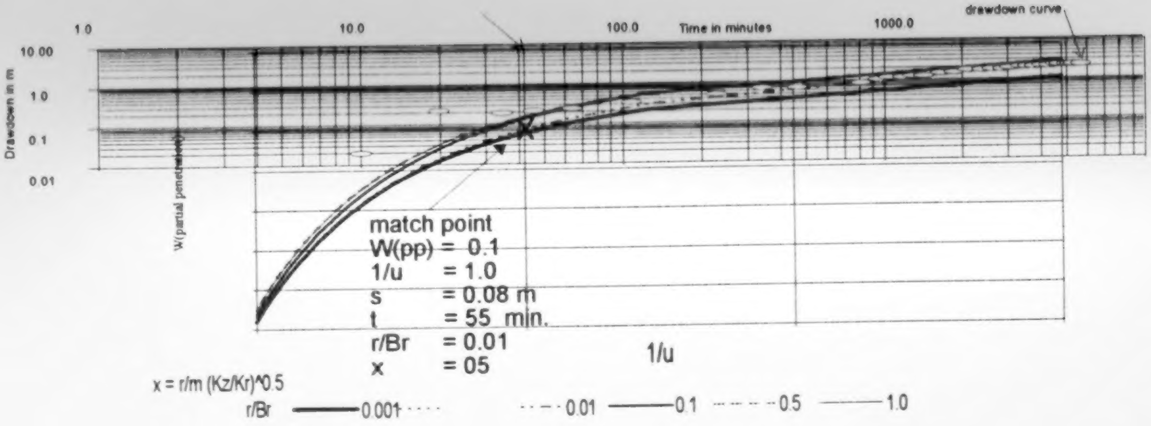


Figure 3.14d Time drawdown curve for P3 during pump test WW4

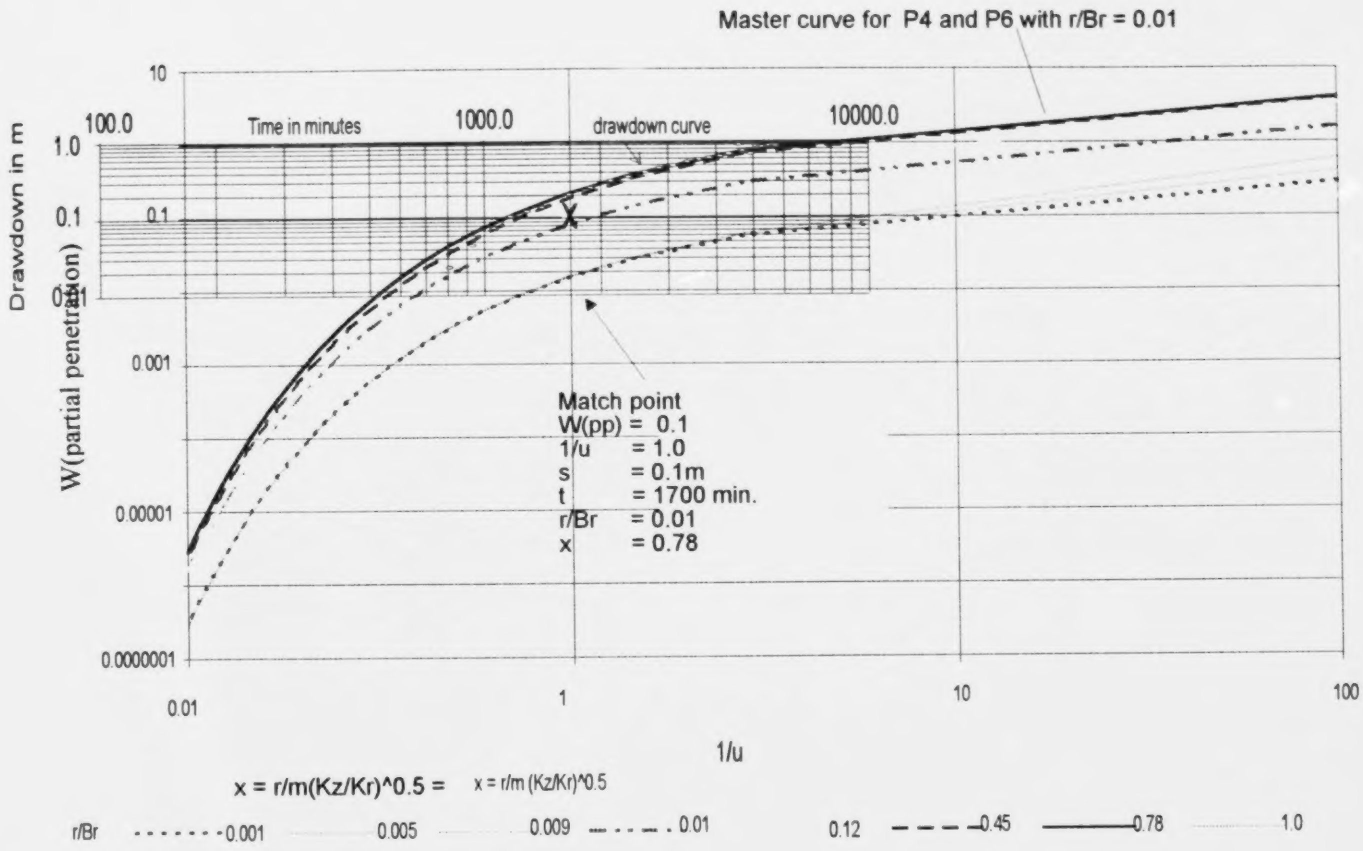


Figure 3.14e Time drawdown curve for P4 pump test WW4

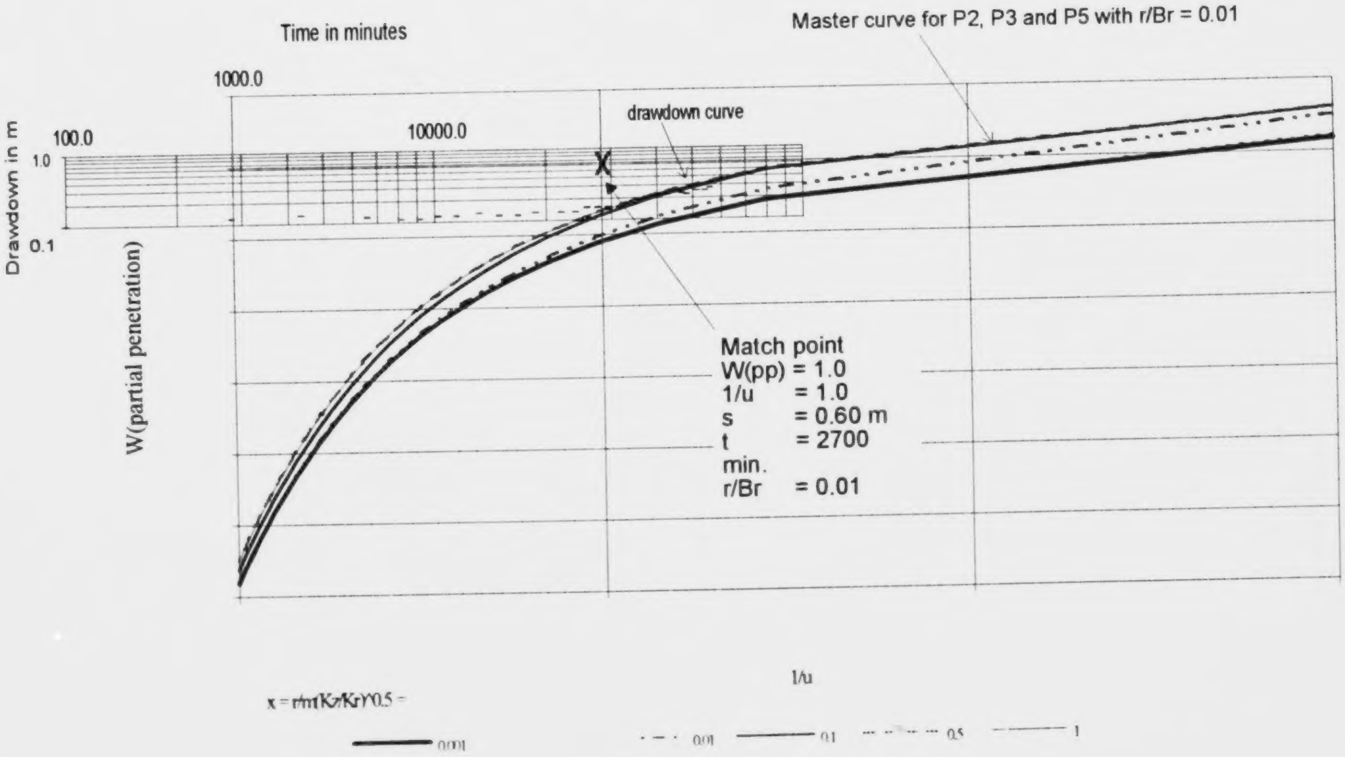


Figure 3.14f Time drawdown curve for P5 during pump test WW4

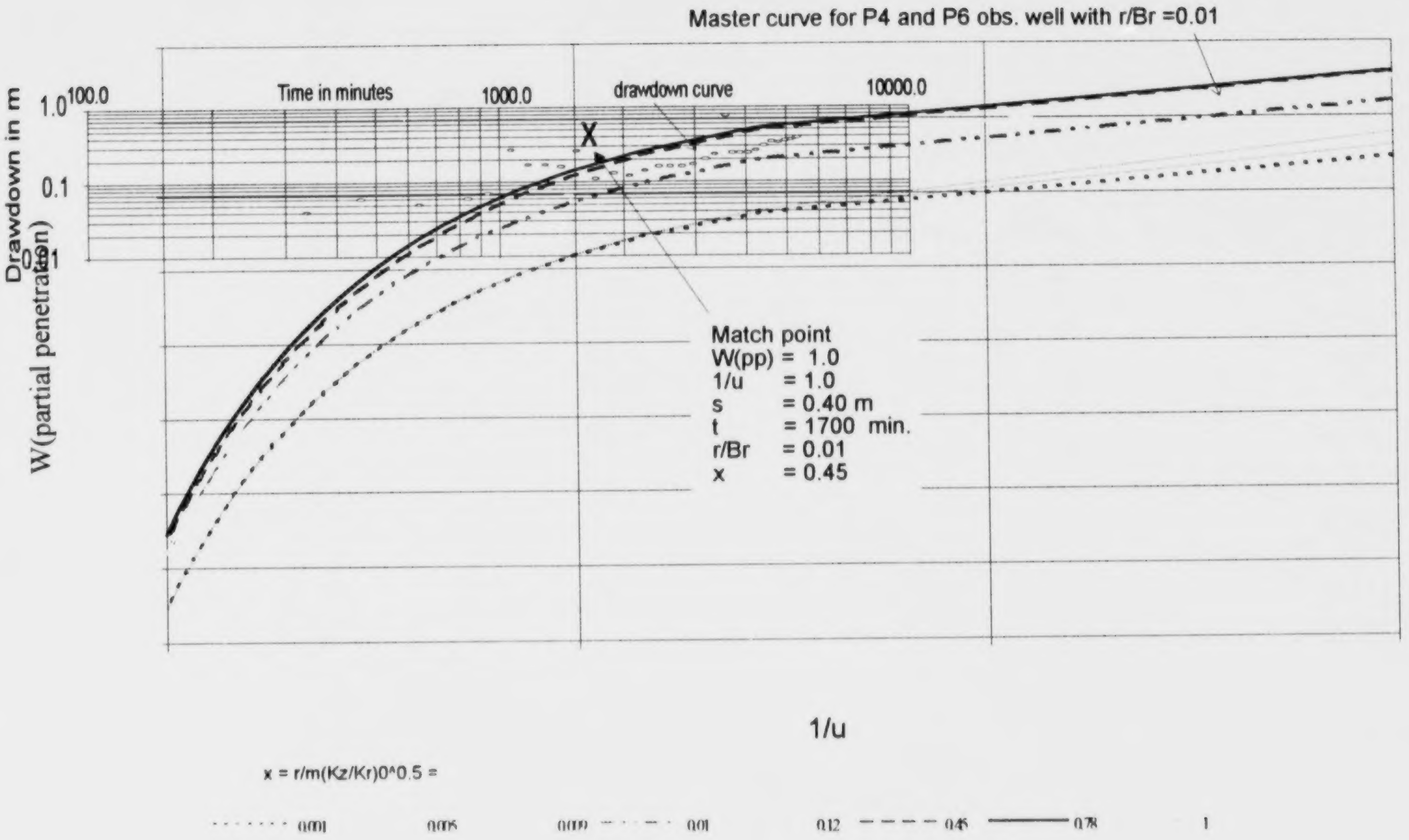


Figure 3.14g Time drawdown curve for P6 during pump test WW4

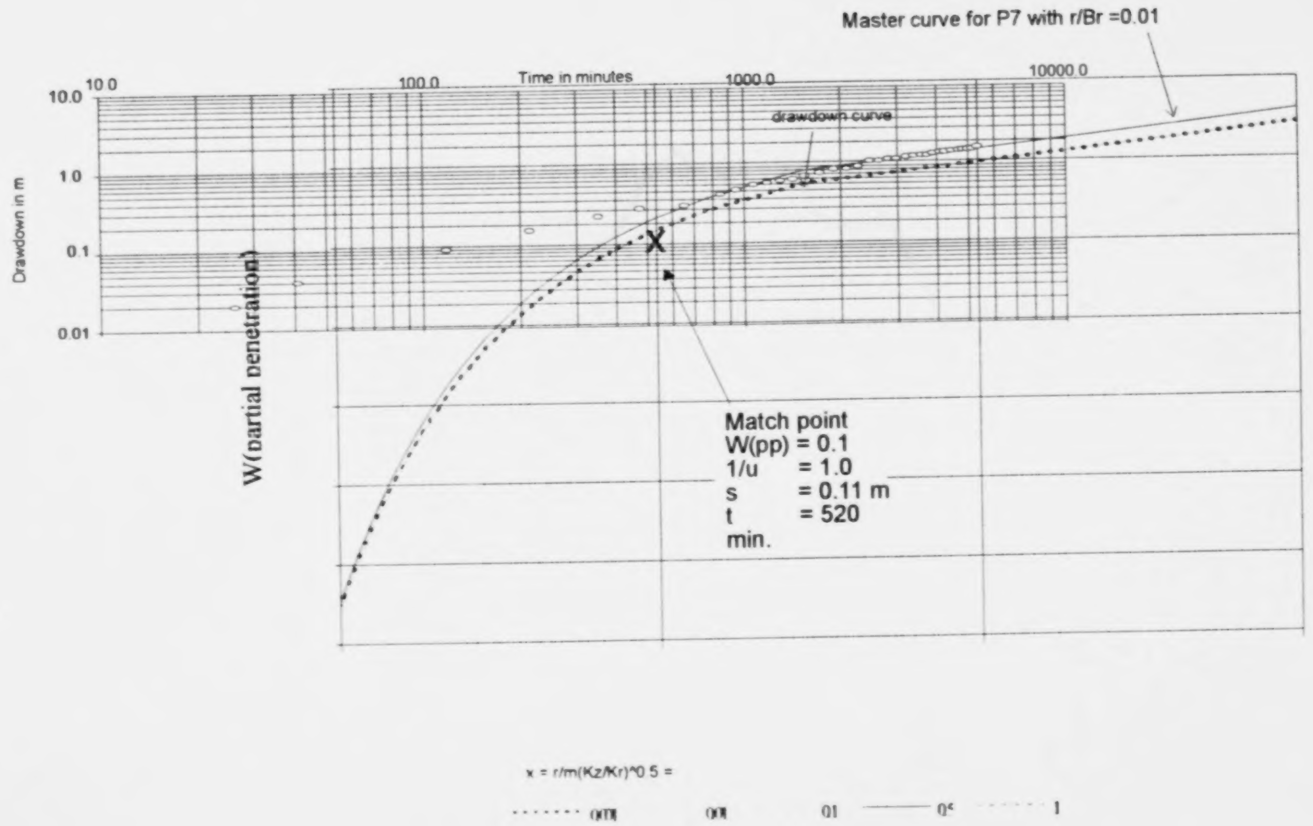


Figure 3.14h Time drawdown curve for P7 during pump test WW4

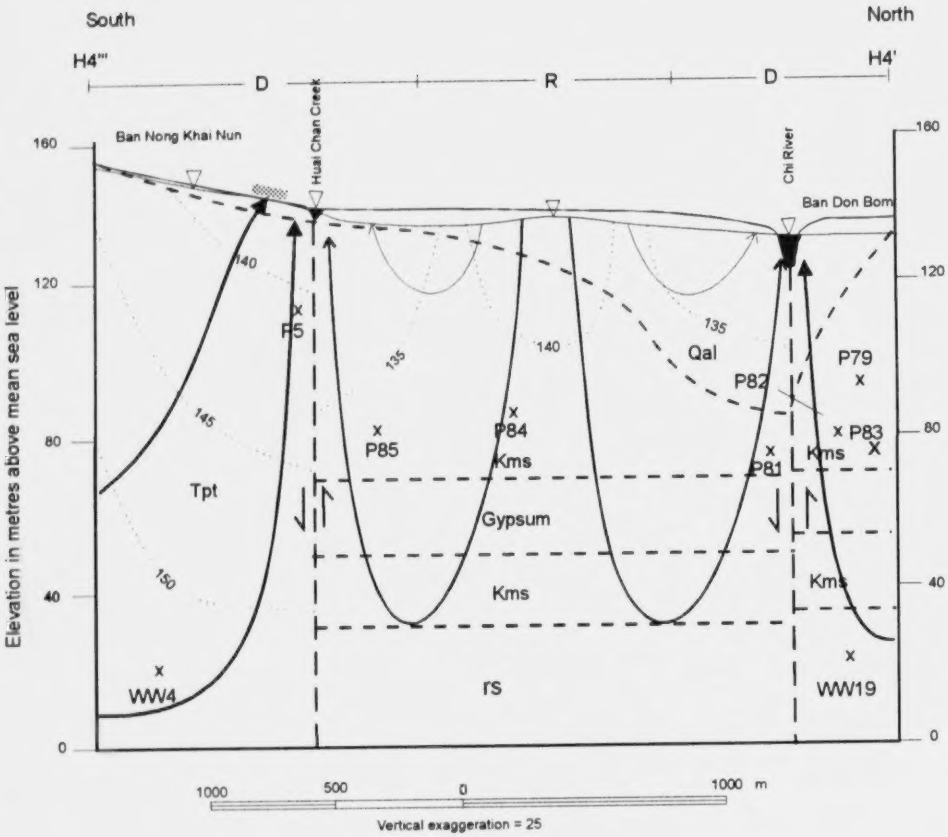

South
North
H4'''
H4'
D
R
D
Huai Chan Creek
Chi River
Ban Nong Khai Nun
Ban Don Bom
160
120
80
40
0
Elevation in metres above mean sea level
140
145
150
135
140
135
P5
P85
P84
Kms
Gypsum
Kms
Tpt
Qal
P82
P79
P83
P81
Kms
Kms
WW4
WW19
rs
1000
500
0
1000 m
Vertical exaggeration = 25

Figure 3.15 Hydrogeolic profile along H4''' - H4'

150	Line of equal hydraulic head with elevation above m.s.l. in m.
	Flow line
→	Local flow
→	Intermediate flow
➡	Regional flow
∼	Land surface
▽	Water table
▨	Area of observed flowing wells
R	Recharge area (downward flow)
D	Discharge area (upward flow)

x	Bottom of wells
x P5	piezometers
- -	Geologic boundary
⇄	Fault
Qal	Alluvium
Tpt	Phu Tok unit
Kms	Mahasarakham unit
rs	Rocksalt unit

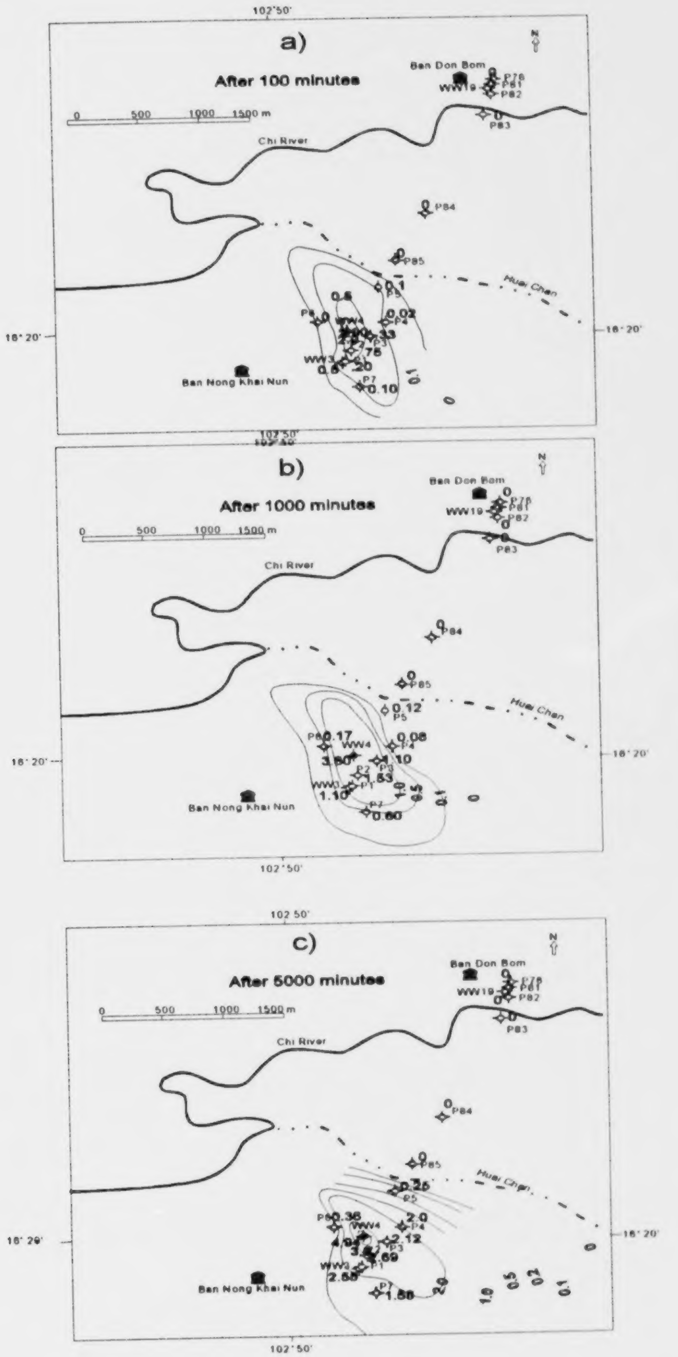

a)
After 100 minutes
b)
After 1000 minutes
c)
After 5000 minutes
N
0 500 1000 1500 m
Ban Don Bom
Ban Nong Khai Nun
Chi River
Huai Chan
WW19
WW4
WW3
P78
P81
P82
P83
P84
P85
P1
P2
P3
P4
P5
P6
P7
102°50'
18°20'

Figure 3.16 Changes in water levels in metres during pumping WW4

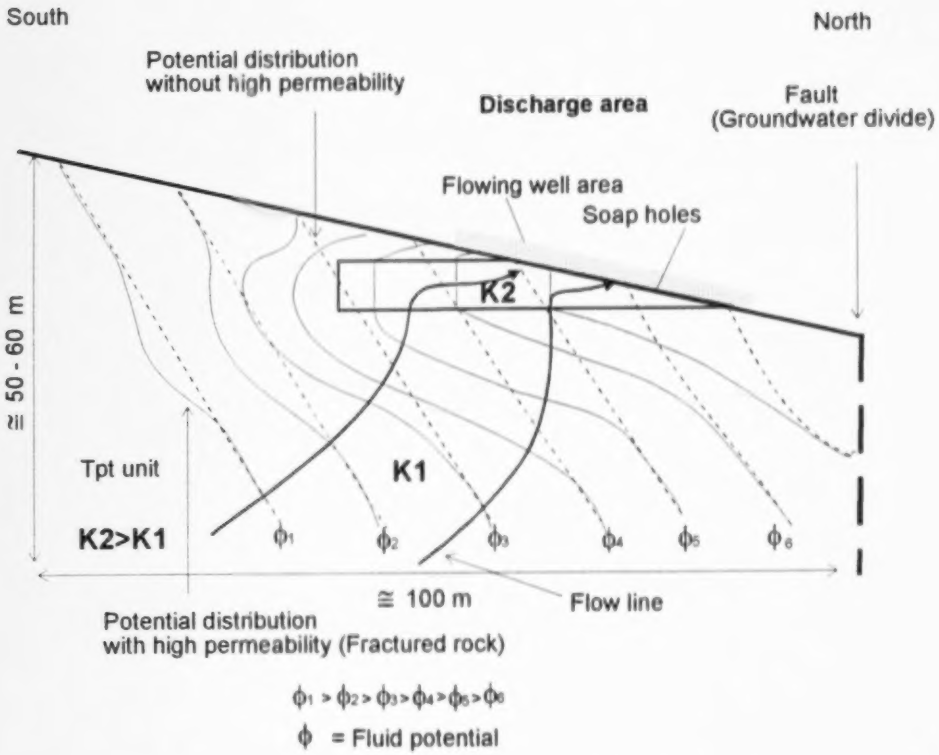

South
North
Potential distribution without high permeability
Discharge area
Fault (Groundwater divide)
Flowing well area
Soap holes
K2
≅ 50 - 60 m
Tpt unit
K1
K2>K1
ϕ_1
ϕ_2
ϕ_3
ϕ_4
ϕ_5
ϕ_6
≅ 100 m
Flow line
Potential distribution with high permeability (Fractured rock)
$\phi_1 > \phi_2 > \phi_3 > \phi_4 > \phi_5 > \phi_6$
ϕ = Fluid potential

Figure 3.17 Diagrammatic representation of the flow pattern associated with a high permeability lens (highly fractured) in a discharge area at Ban Nong Khai Nun

(modified from Clissold, 1967)

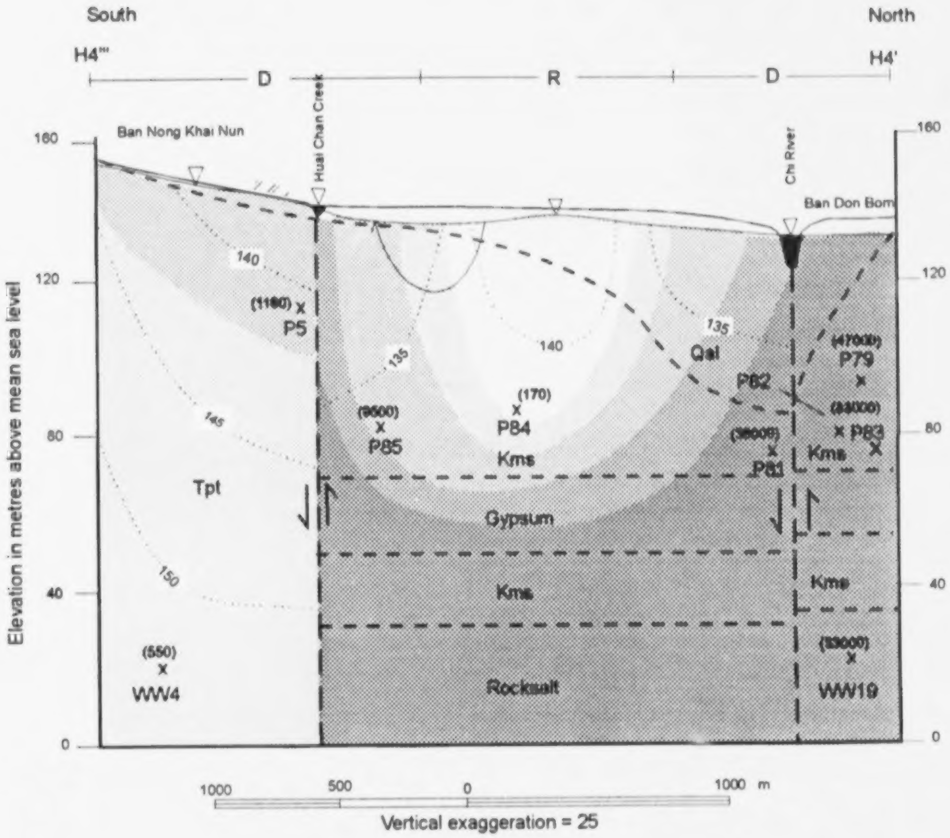

South
North
H4'''
H4'
D
R
D
Hual Chan Creek
Chi River
Ban Nong Khai Nun
Ban Don Bom
Elevation in metres above mean sea level
160
120
80
40
0
140
135
140
135
145
150
(1180) x P5
(9600) x P85
(170) x P84
Kms
Qal
P82
(36000) x P81
(47000) P79 x
(33000) x P83
Kms
Tpt
Gypsum
Kms
Rocksalt
(550) x WW4
(33000) x WW19
1000
500
0
1000 m
Vertical exaggeration = 25

Figure 3.18 Distribution of TDS contents along H4''' - H4'

··150··	Line of equal hydraulic head with elevation above m.s.l. in m.
	Land surface
▽	Water table
⁄⁄ ⁄⁄	Area of observed flowing wells
R	Recharge area (downward flow)
D	Discharge area (upward flow)
x	Bottom of wells and piezometers
— —	Geologic boundary
⇄	Concealed fault

Qal	Alluvium
Tpt	Phu Tok unit
Kms	Mahasarakham unit
(150)	TDS contents in mg/l
	100 - 500
░	500 - 1000
░	1000 - 10000
▒	10000 - 30000
▓	> 30000

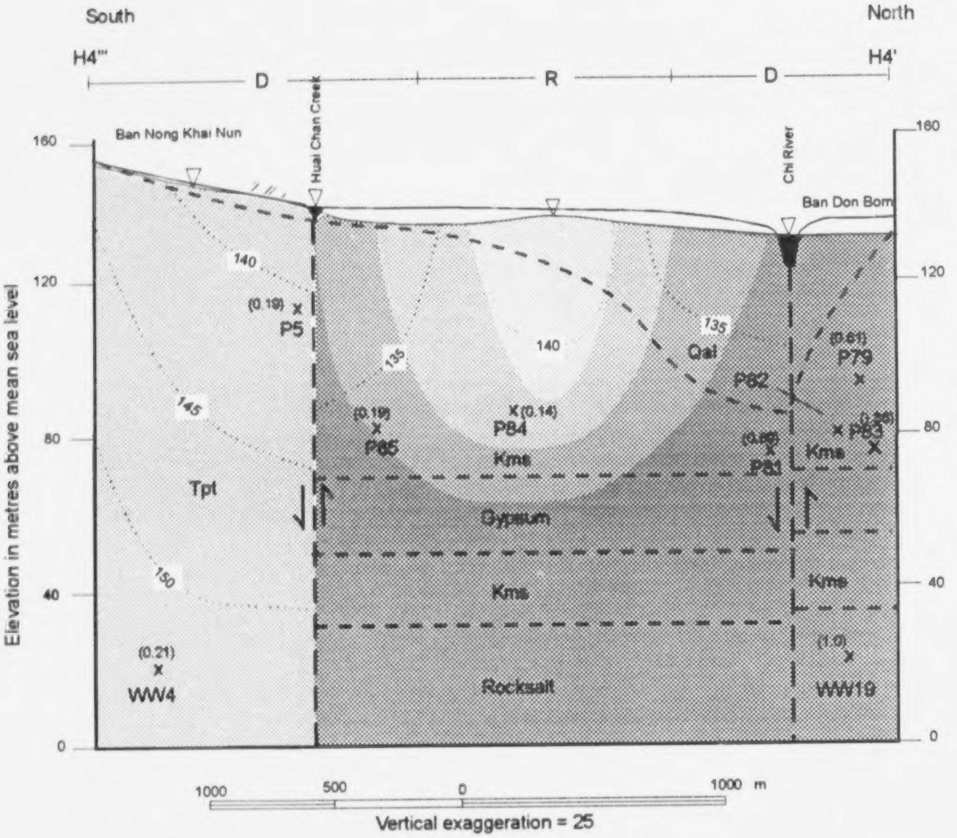

South
North
H4'''
H4'
D
R
D
Ban Nong Khai Nun
Huai Chan Creek
Chi River
Ban Don Bom
160
120
80
40
0
Elevation in metres above mean sea level
140
145
150
135
140
135
(0.19)
P5
(0.19)
P85
(0.14)
P84
Kms
Qal
P82
(0.61)
P79
(0.36)
P83
(0.60)
P81
Kms
Tpt
Gypsum
Kms
Kms
Rocksalt
(0.21)
WW4
(1.0)
WW19
1000
500
0
1000 m
Vertical exaggeration = 25

Figure 3.19 Distribution of Mg : Ca ratio along H4''' - H4'

150 Line of equal hydraulic head with elevation above m.s.l. in m.
Land surface
Water table
Area of observed flowing wells
R Recharge area (downward flow)
D Discharge area (upward flow)
x Bottom of wells and piezometers
Geologic boundary
Concealed fault

Qal Alluvium
Tpt Phu Tok unit
Kms Mahasarakham unit
(0.1) Mg : Ca ratio

<0.1

0.1 - 0.3

0.3 - 0.6

>0.6

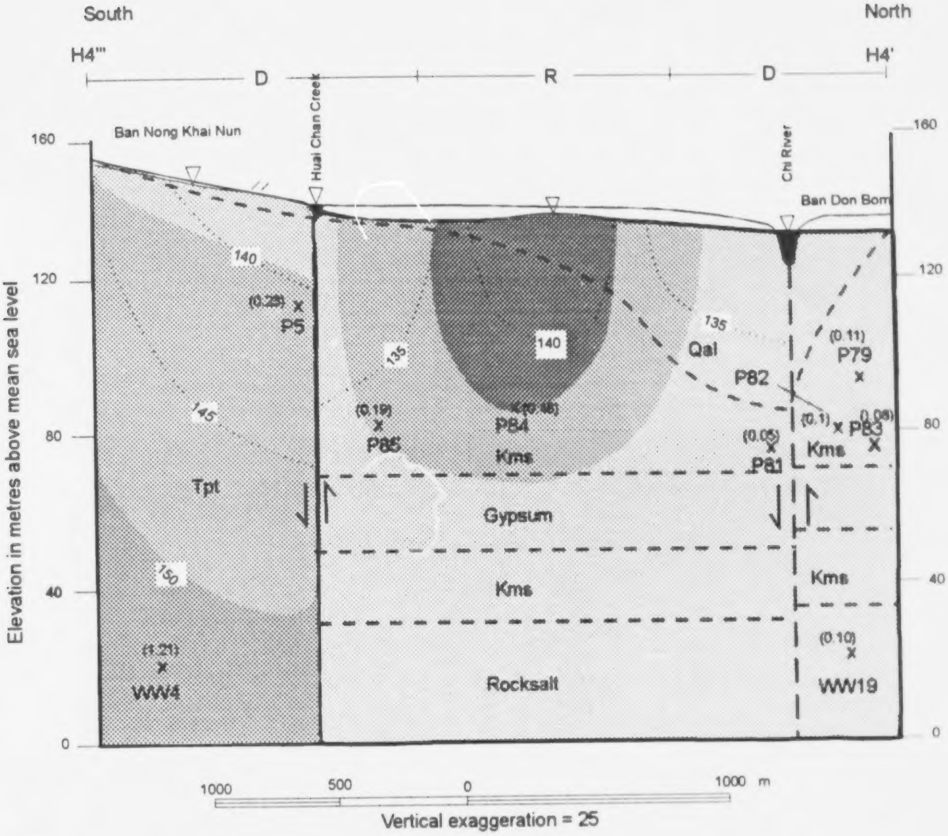

South
North
H4'''
H4'
D
R
D
Ban Nong Khai Nun
Huai Chan Creek
Chi River
Ban Don Bom
160
120
80
40
0
Elevation in metres above mean sea level
140
145
150
135
140
135
(0.23) x
P5
(0.19)
x
P85
x (0.98)
P84
Kms
Qal
P82
(0.11)
P79
x
(0.05)
x
P81
(0.1) x P83
(0.08)
x
Kms
Tpt
Gypsum
Kms
Kms
Rocksalt
(1.21)
x
WW4
(0.10)
x
WW19
1000
500
0
1000 m
Vertical exaggeration = 25

Figure 3.20 Distribution of Ca : Na ratio along H4''' - H4'

··150·· Line of equal hydraulic head with elevation above m.s.l. in m.
Land surface
Water table
Area of observed flowing wells
R Recharge area (downward flow)
D Discharge area (upward flow)
x Bottom of wells and piezometers
– – – Geologic boundary
Concealed fault

Qal Alluvium
Tpt Phu Tok unit
Kms Mahasarakham unit
(0.1) Ca : Na ratio

░ <0.1
▒ 0.1 - 0.5
▨ >0.5 - 1.0
▓ >1.0

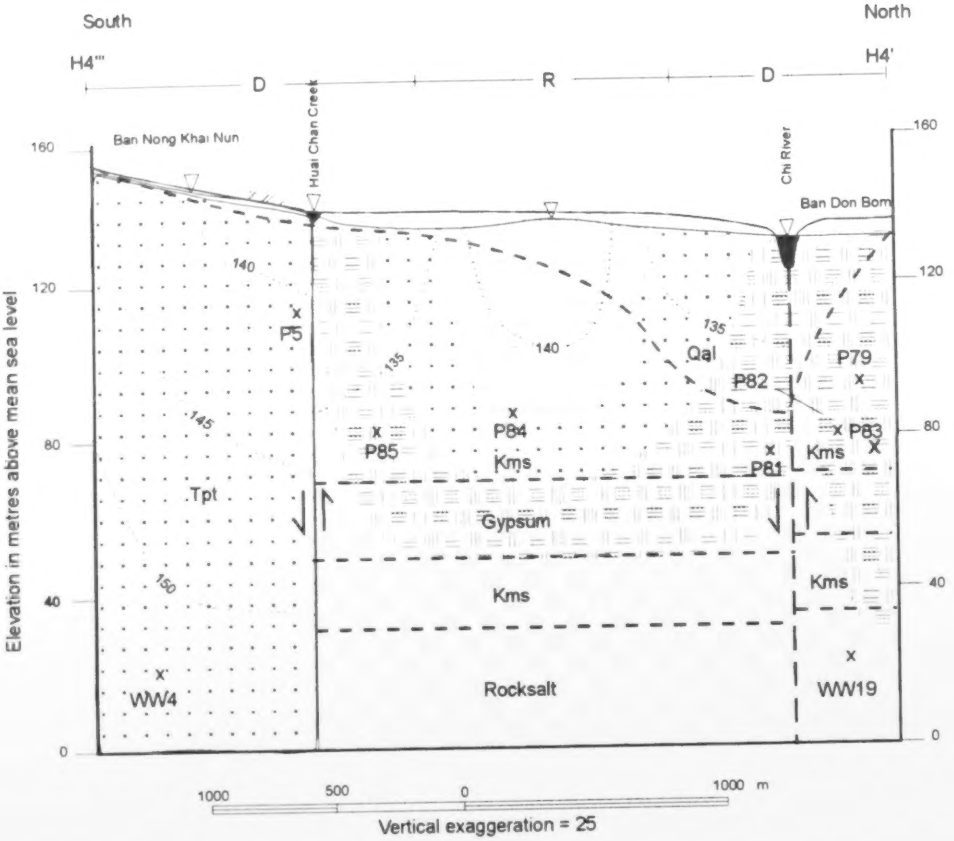
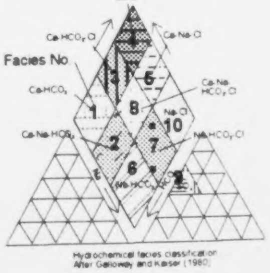

South
North
H4'''
H4'
D
R
D
Huai Chan Creek
Chi River
Ban Nong Khai Nun
Ban Don Bom
160
120
80
40
0
Elevation in metres above mean sea level
140
135
145
150
140
135
Qal
Tpt
Kms
Gypsum
Kms
Rocksalt
P5
P85
P84
P82
P81
P79
P83
Kms
Kms
WW4
WW19
1000
500
0
1000 m
Vertical exaggeration = 25

Figure 3.21 Hydrochemical facies along H4''' - H4'

150 Line of equal hydraulic head with elevation above m.s.l. in m.
Land surface
Water table
Area of observed flowing wells
R Recharge area (downward flow)
D Discharge area (upward flow)
x Bottom of wells and piezometers
Geologic boundary
Concealed fault

Qal Alluvium
Tpt Phu Tok unit
Kms Mahasarakham unit
Hydrochemical facies classification


Ca-Cl
Ca-HCO3-Cl
Ca-Na-Cl
Facies No
Ca-HCO3
Ca-Na-HCO3-Cl
Na-Cl
Ca-Na-HCO3
Na-HCO3-Cl
Na-HCO3
1
2
3
4
5
6
7
8
9
10

Hydrochemical facies classification After Galloway and Kaiser (1980)

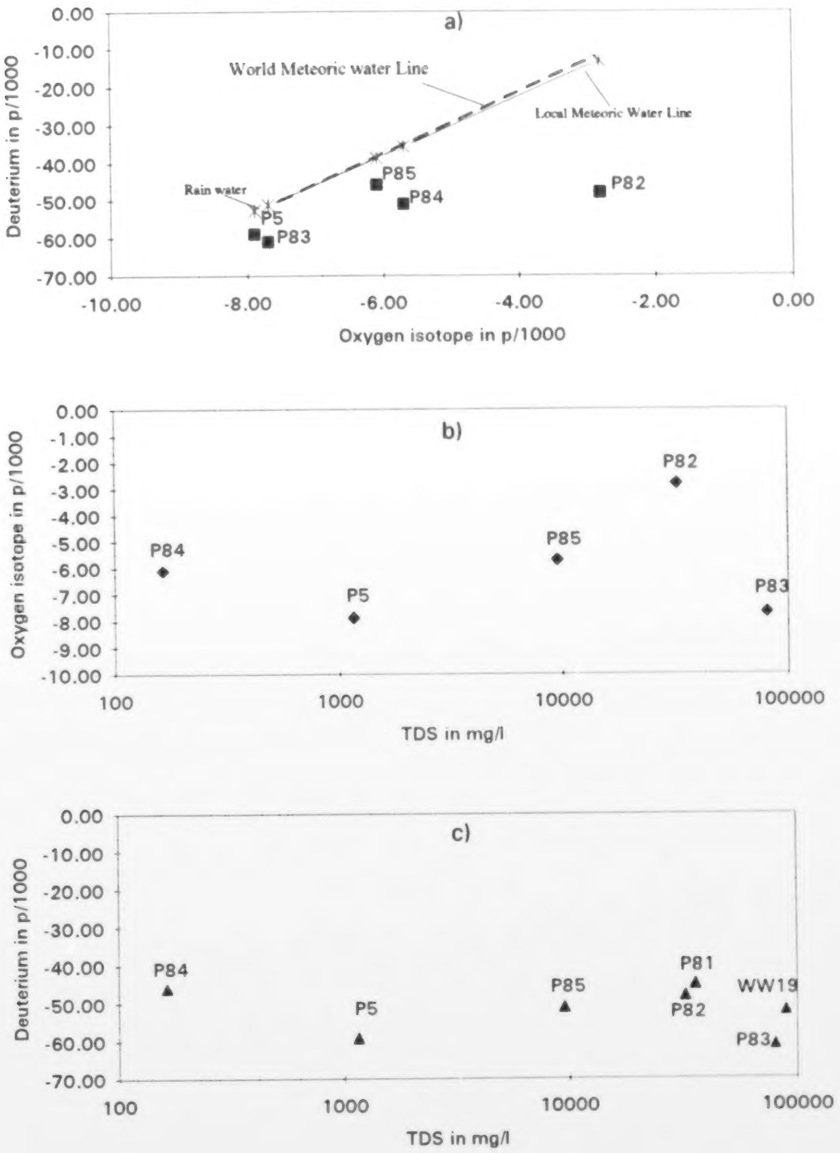


Figure 3.22 Stable isotopic compositions of groundwater at Ban Nong Khai Nun

a) Hydrogen and oxygen delta values

b) Oxygen isotope delta values and total dissolve solid

c) Deuterium isotopic delta values and total disolve solid

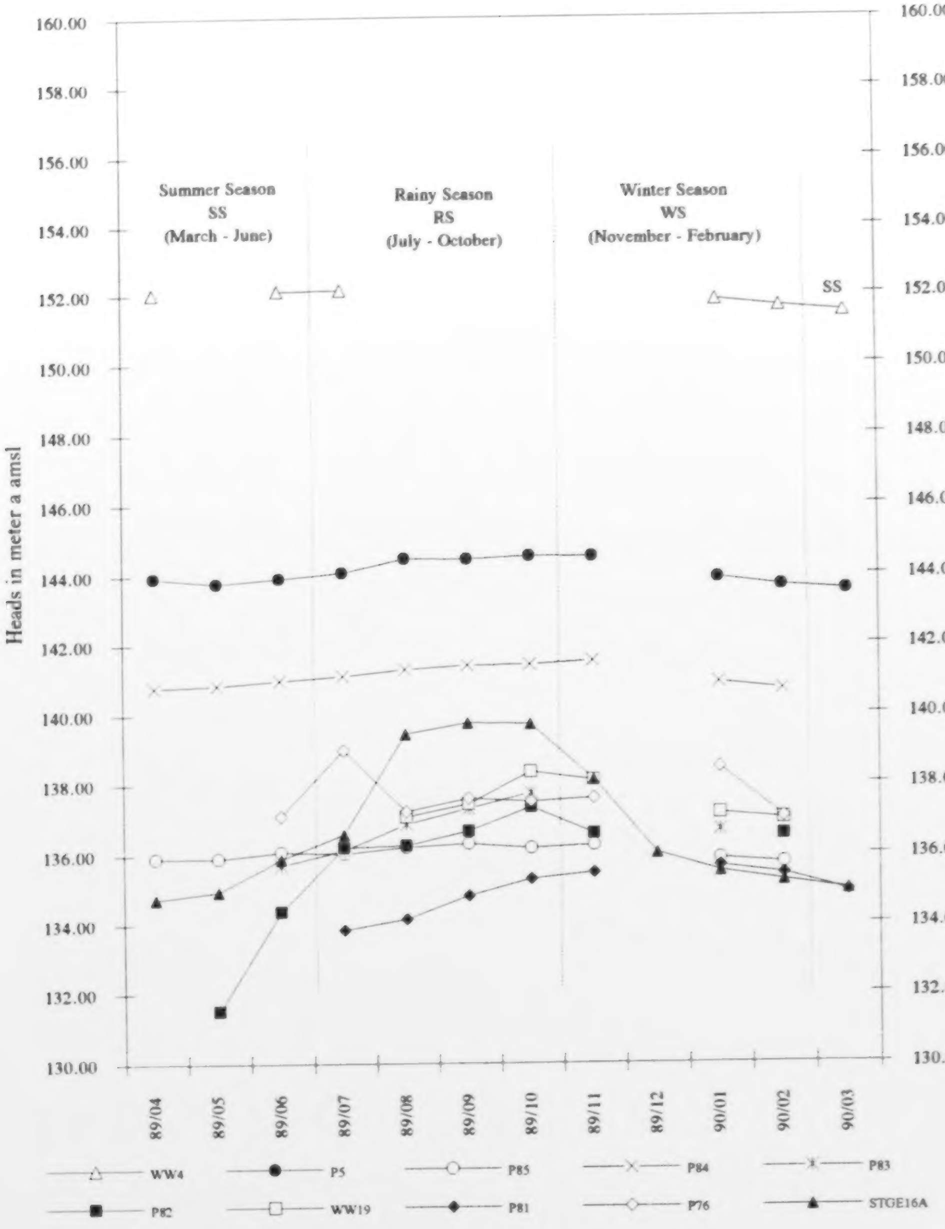


Figure 3.23 Monthly hydraulic head fluctuations along the hydrogeologic profile H4''' - H4'

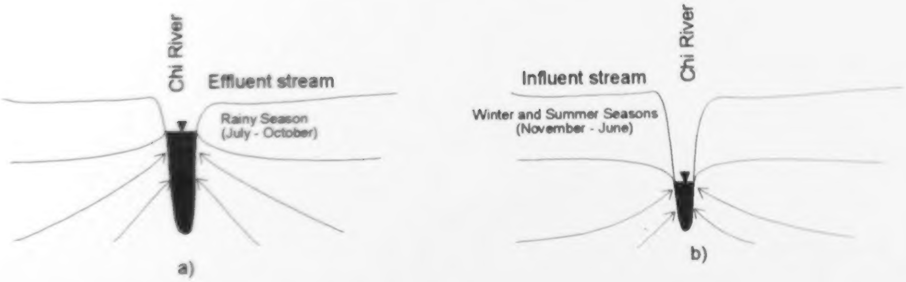

Chi River
Effluent stream
Rainy Season
(July - October)
a)
Influent stream
Chi River
Winter and Summer Seasons
(November - June)
b)

Figure 3.24 Conceptual model of groundwater flow and stream interaction in a discharge area

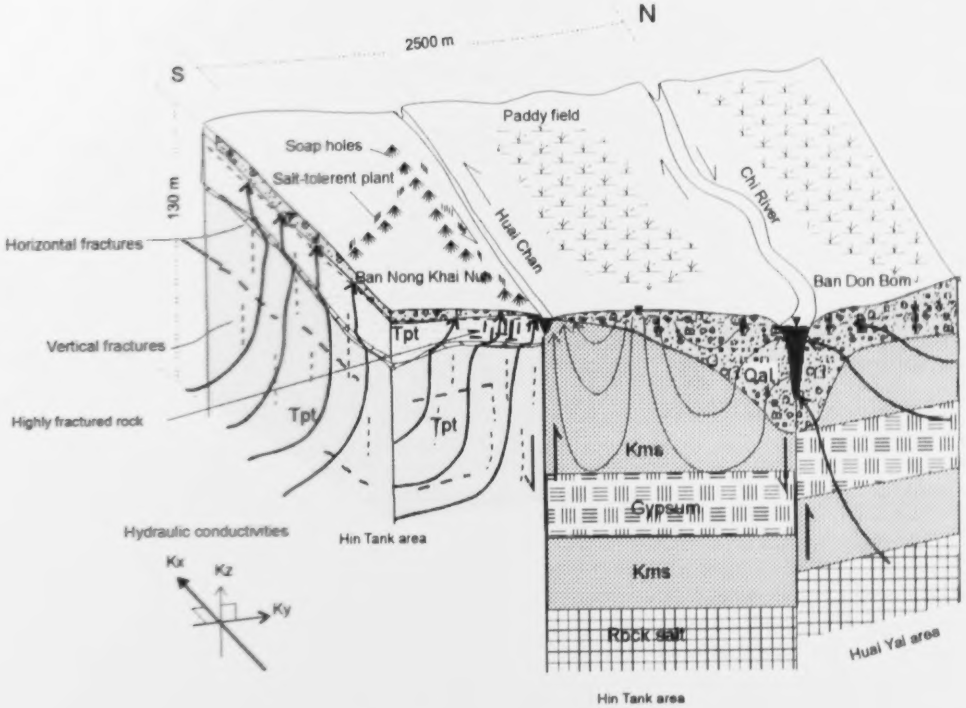

N
2500 m
S
130 m
Paddy field
Soap holes
Salt-tolerent plant
Huai Chan
Chi River
Horizontal fractures
Ban Nong Khai Nun
Ban Don Bom
Vertical fractures
Tpt
Tpt
Tpt
Qal
Highly fractured rock
Kms
Gypsum
Kms
Rock salt
Hydraulic conductivities
Hin Tank area
Kx
Kz
Ky
Huai Yai area
Hin Tank area

Figure 3.25 Diagrammatic representation of conceptual groundwater flow at Ban Nong Khai Nun

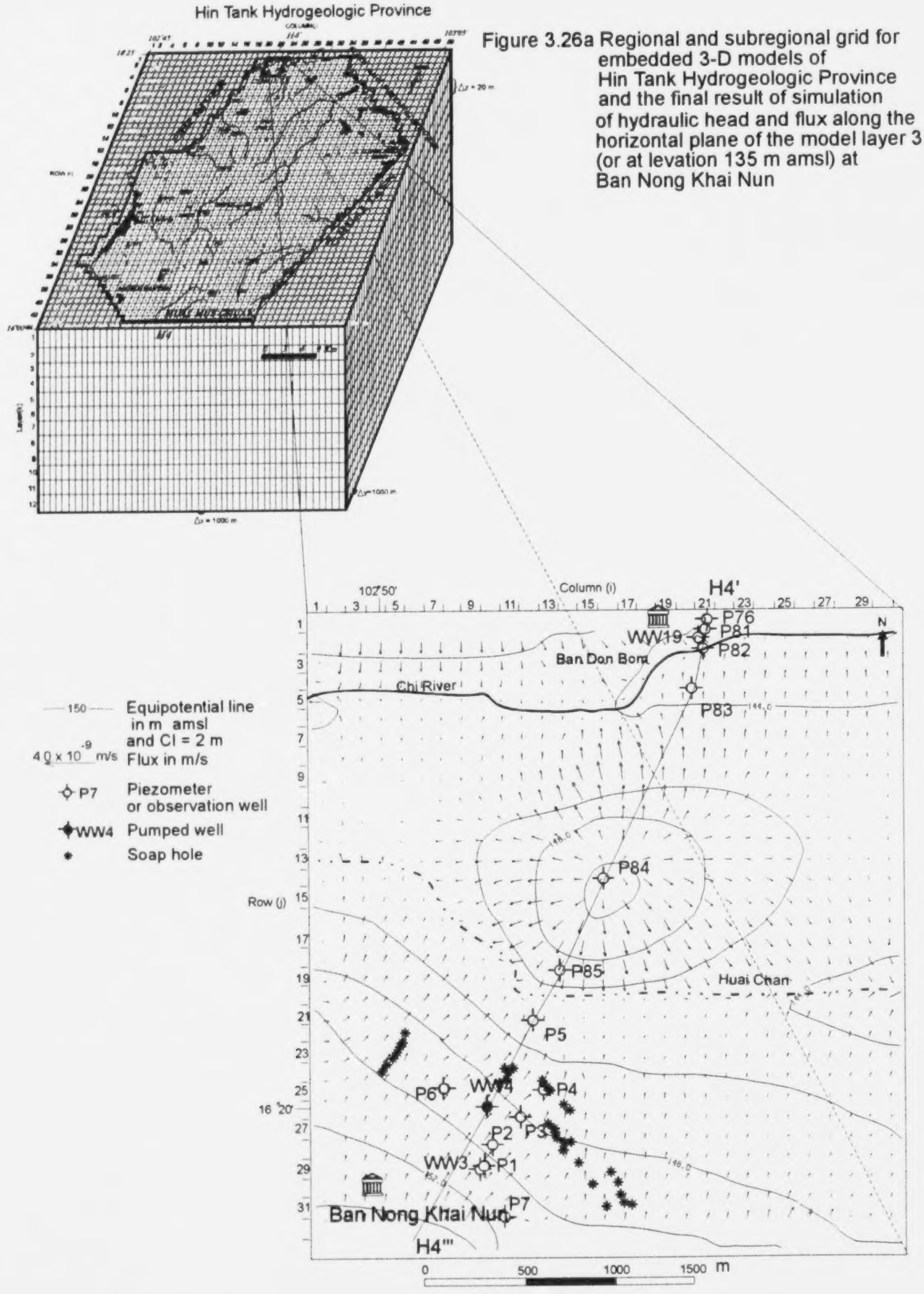

Hin Tank Hydrogeologic Province
Δz = 20 m
Δy=1000 m
Δx = 1000 m
102°50'
Column (i)
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
H4'
P76
WW19
P81
P82
Ban Don Bom
Chi River
P83
144.0
146.0
P84
P85
Huai Chan
P5
P6
WW4
P4
P2
P3
WW3
P1
P7
Ban Nong Khai Nun
H4'''
Row (j)
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
16°20'
N
0 500 1000 1500 m
150 Equipotential line in m amsl and CI = 2 m
4.0 x 10⁻⁹ m/s Flux in m/s
P7 Piezometer or observation well
WW4 Pumped well
Soap hole

Figure 3.26a Regional and subregional grid for embedded 3-D models of Hin Tank Hydrogeologic Province and the final result of simulation of hydraulic head and flux along the horizontal plane of the model layer 3 (or at levation 135 m amsl) at Ban Nong Khai Nun

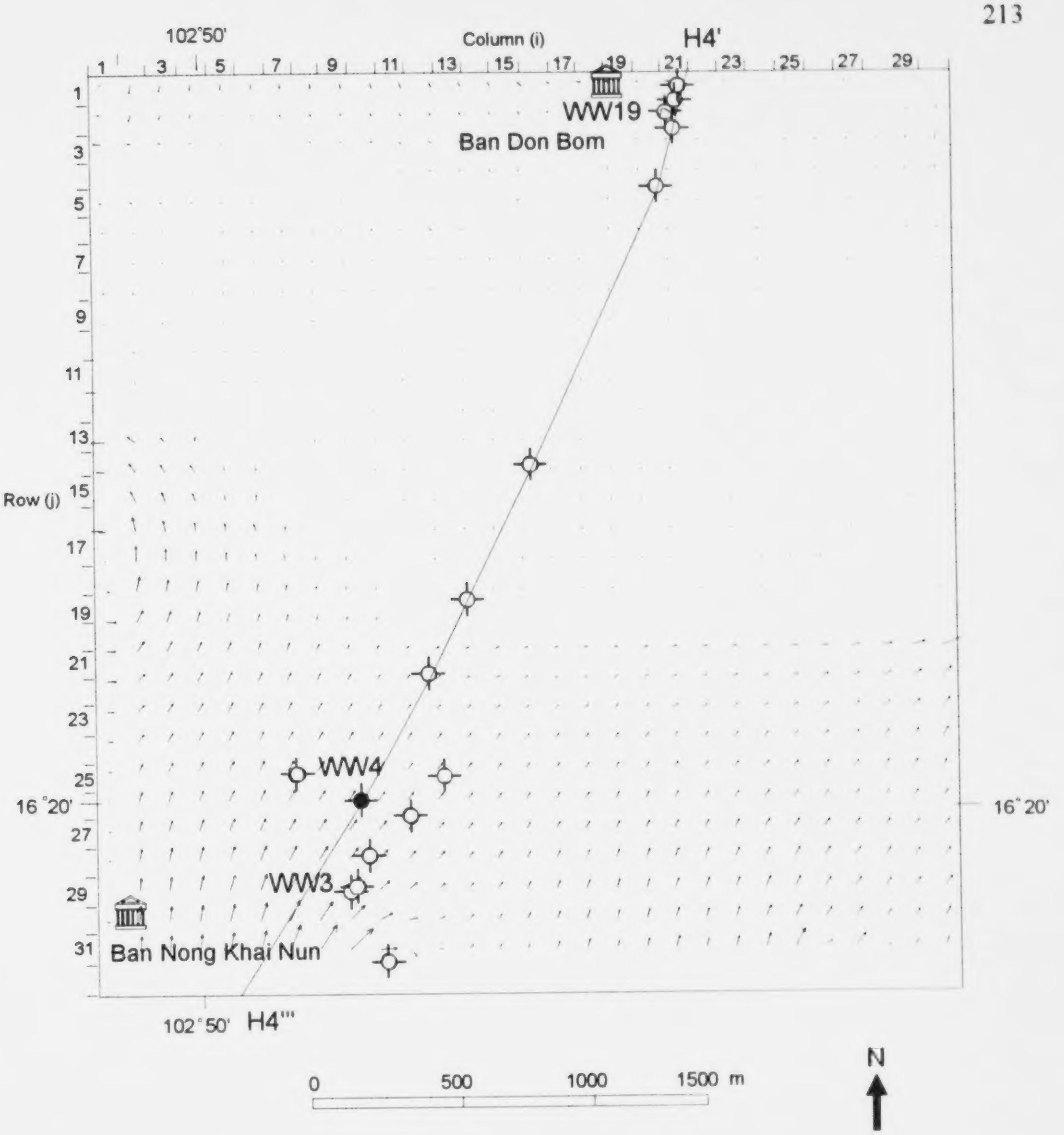
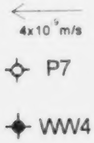

102°50'
Column (i)
H4'
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
Row (j)
WW19
Ban Don Bom
WW4
WW3
Ban Nong Khai Nun
16°20'
16°20'
102°50'
H4'''
0
500
1000
1500 m
N

Figure 3.26b Simulated fluxes along the horizontal plane at elevation 30 m amsl or model layer 10


4x10⁻⁵ m/s
P7
WW4

Flux in m/s

Piezometer or observation well

Pumped well

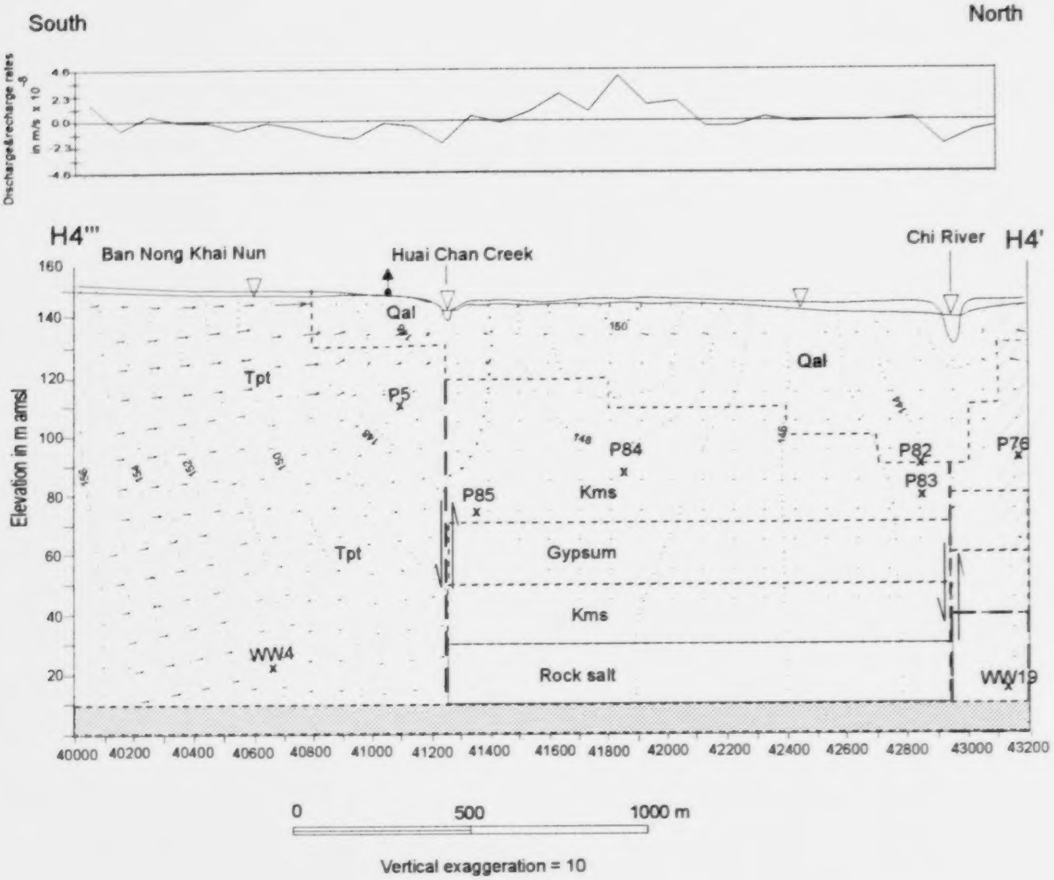
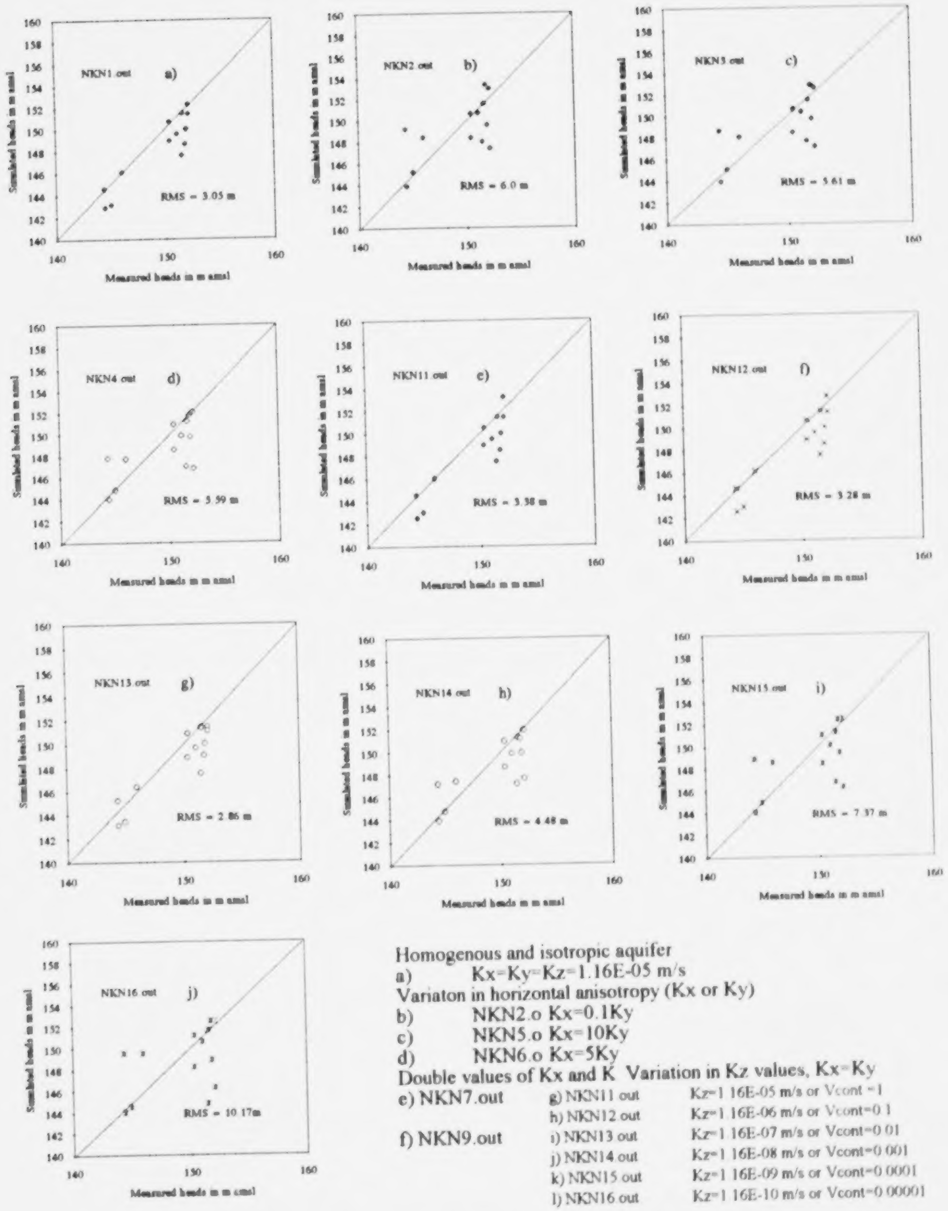

South
North
Discharge&recharge rates in m/s x 10^-8
4.0
2.3
0.0
-2.3
-4.0
H4'''
Ban Nong Khai Nun
Huai Chan Creek
Chi River
H4'
Elevation in m amsl
160
140
120
100
80
60
40
20
Qal
Tpt
P5
150
148
146
144
156
154
152
P84
Kms
P82
P83
P76
P85
Gypsum
Kms
Rock salt
WW4
WW19
40000
40200
40400
40600
40800
41000
41200
41400
41600
41800
42000
42200
42400
42600
42800
43000
43200
0
500
1000 m
Vertical exaggeration = 10

Figure 3.27 Simulated hydraulic heads and fluxes along H4''' - H4'

150	Line of equal hydraulic head with elevation above m.s.l. in m. and contour interval = 2 m	Qal	Alluvium
		Tpt	Phu Tok unit
18×10^{-6}	Flux in m/s	Kms	Mahasarakham unit
↑	Area of observed flowing wells	▽	Water table
P85 x	Water well and piezometer	☐	Constant head boundary
- - - - -	Lithologic boundary	▨	No flow boundary
⇄	Concealed fault		



Homogenous and isotropic aquifer
a) Kx=Ky=Kz=1.16E-05 m/s
Variaton in horizontal anisotropy (Kx or Ky)
b) NKN2.o Kx=0.1Ky
c) NKN5.o Kx=10Ky
d) NKN6.o Kx=5Ky

Double values of Kx and K

e) NKN7.out

f) NKN9.out

Variation in Kz values, Kx=Ky

g) NKN11 out Kz=1 16E-05 m/s or Vcont =1
h) NKN12 out Kz=1 16E-06 m/s or Vcont=0 1
i) NKN13 out Kz=1 16E-07 m/s or Vcont=0 01
j) NKN14 out Kz=1 16E-08 m/s or Vcont=0 001
k) NKN15 out Kz=1 16E-09 m/s or Vcont=0 0001
l) NKN16 out Kz=1 16E-10 m/s or Vcont=0 00001

Figure 3.28 Linear regression between measured and simulated hydraulic heads at Ban Nong Khai Nun Area

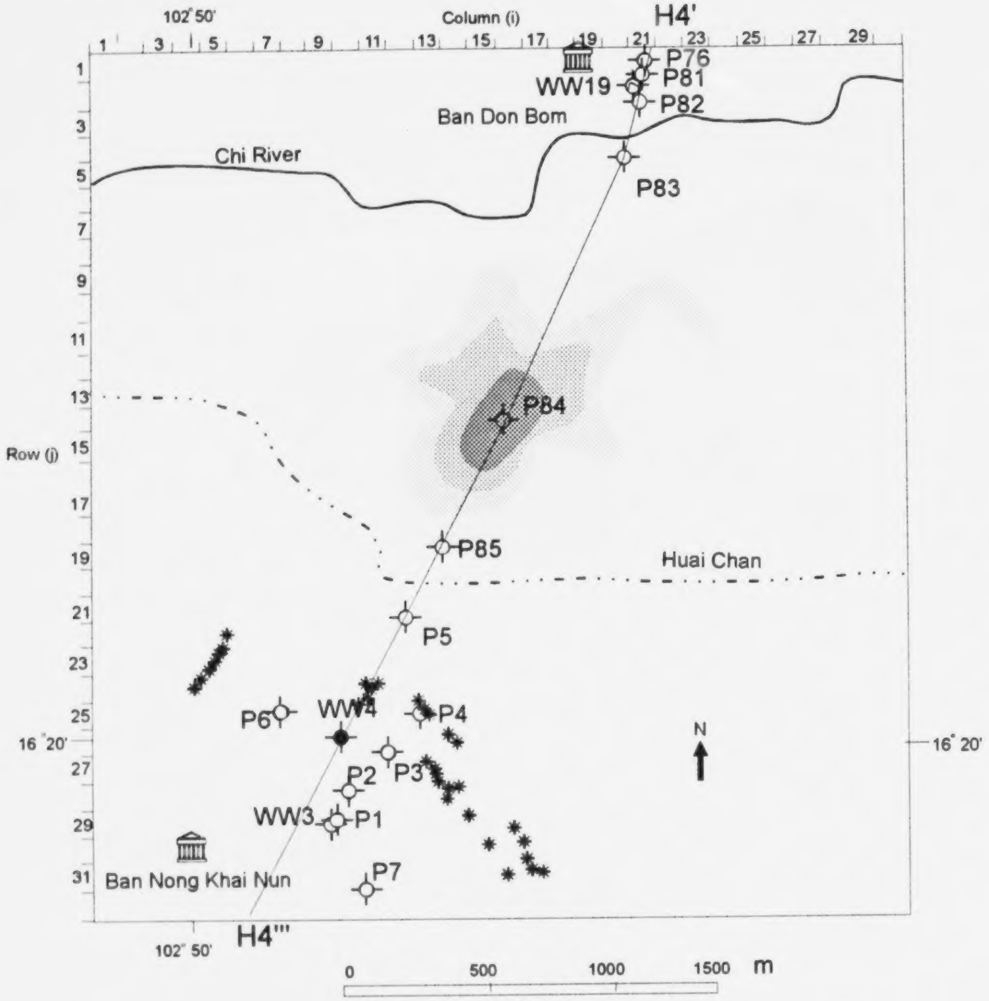

102° 50'
Column (i)
H4'
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
Row (j)
P76
P81
WW19
P82
Ban Don Bom
Chi River
P83
P84
P85
Huai Chan
P5
P6
WW4
P4
16° 20'
N
P2
P3
WW3
P1
Ban Nong Khai Nun
P7
102° 50'
H4'''
0
500
1000
1500
m

Figure 3.29 Distribution of simulated recharge rates for Ban Nong Khai Nun

Recharge rates in m/s (E10^{-5})

>0.0 - 0.5

░ 0.5 - 1.0

▒ 1.0 - 5.0

▓ 5.0 - 2.5

-¤- P7 Piezometer or observation well

-●- WW4 Pumped well

✱ Soap hole

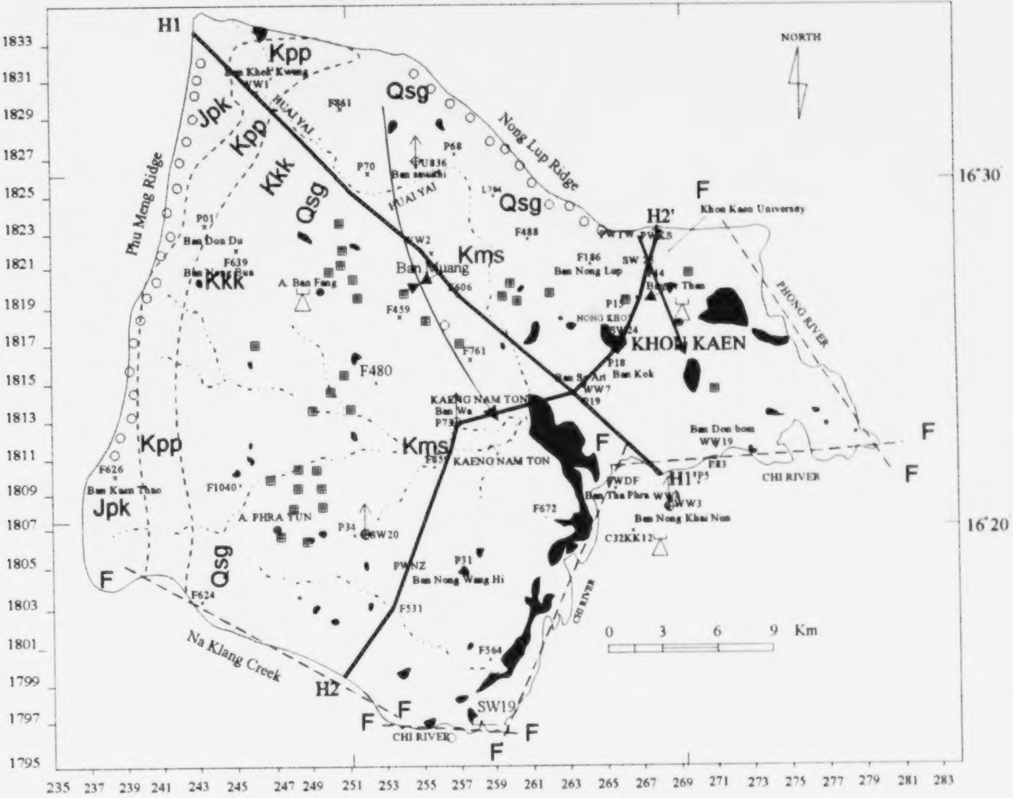

102°40
102°50
16°30
16°20
NORTH
H1
H1'
H2
H2'
Kpp
Jpk
Kkk
Qsg
Kms
F
Phu Meng Ridge
Nong Lup Ridge
HUAI YAI
Na Klang Creek
CHI RIVER
PHONG RIVER
KHON KAEN
KAENG NAM TON
Khon Kaen University
Ban Muang
A. Ban Fang
A. PHRA YUN
Ban Nong Lup
Ban Kok
Ban Don Du
Ban Kaen Thao
Ban Nong Wang Hi
Ban Nong Khai Nun
Ban Don bom
Ban Tha Phra
WW1
WW2
WW3
WW7
WW19
SW19
SW20
SW24
P01
P18
P31
P34
P68
P70
F186
F459
F480
F488
F531
F564
F606
F624
F626
F639
F672
F761
F861
F1040
PWNZ
PWDF
C32KK12
0 3 6 9 Km
1833
1831
1829
1827
1825
1823
1821
1819
1817
1815
1813
1811
1809
1807
1805
1803
1801
1799
1797
1795
235 237 239 241 243 245 247 249 251 253 255 257 259 261 263 265 267 269 271 273 275 277 279 281 283

Figure 4.1 Hydrogeologic map of Huai Yai Hydrogeologic Province

- - -	Stream	Qsg	Sand and gravel unit
▬	Lake or reservoir	Kms	Mahasaraham unit
H1 ___ H1'	Line of hydrogeological profile	Kkk	Khok Kruat unit
•	Amphoe or district	Kpp	Phu Phan unit
═	Road	Jpk	Phu Kraduang unit
WW1	Water wells		
P34	Piezometer		
SW22	Surface water samples		Recharge area
- - - - - - -	Hydrogeologic boundary	○	Discharge area
F - - - - - F	Fault		
→	Anticline and plunge	⧖	Rainfall station
→	Syncline and plunge		Hydrogeologic province boundary
▨	Area of saline soil		
↑	Flowing well		
○○○○○	Surafce water and groundwater divide		

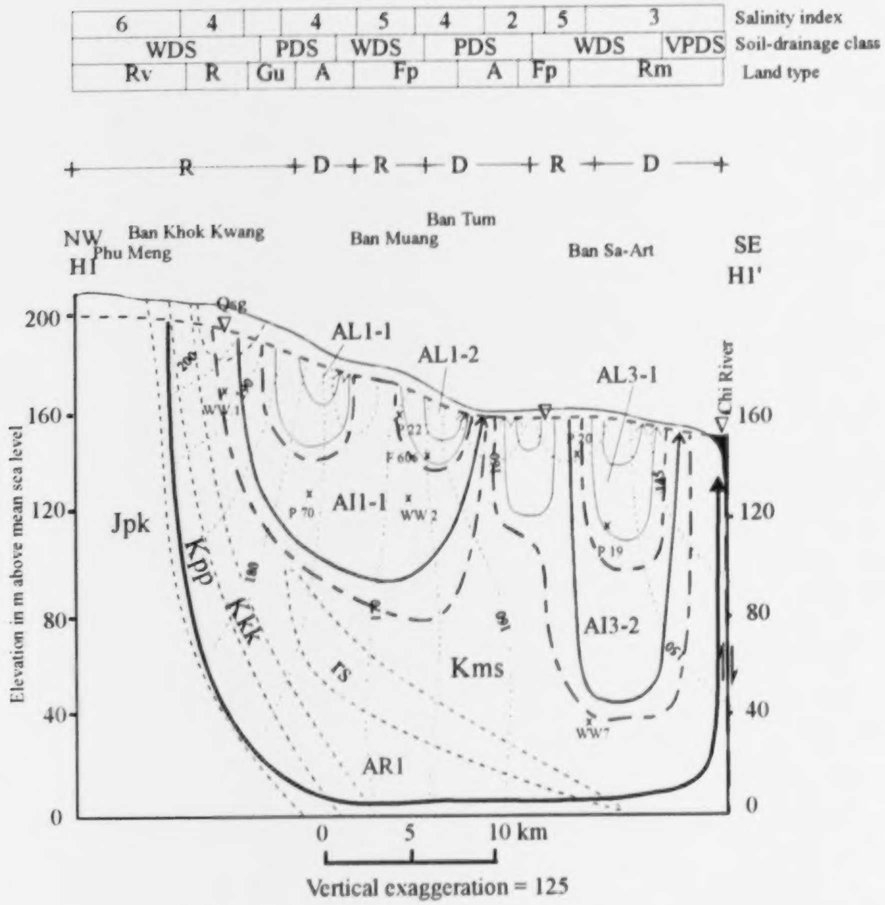

6
4
4
5
4
2
5
3
Salinity index
WDS
PDS
WDS
PDS
WDS
VPDS
Soil-drainage class
Rv
R
Gu
A
Fp
A
Fp
Rm
Land type
R
D
R
D
R
D
NW
H1
Ban Khok Kwang
Phu Meng
Ban Muang
Ban Tum
Ban Sa-Art
SE
H1'
Qsg
AL1-1
AL1-2
AL3-1
Chi River
200
160
120
80
40
0
Elevation in m above mean sea level
WW1
P22
F 60
P 70
AI1-1
WW 2
P 20
P 19
Jpk
Kpp
Kkk
rs
Kms
AI3-2
WW7
AR1
0
5
10 km
Vertical exaggeration = 125

Figure 4.2 Hydrogeologic profile H1- H1'

160	Line of equal hydraulic head with elevation above mean sea level in m
- - ▽ - -	Water table
	Local flow system (AL1-1)
	Intermediate flow system (AI1-1)
	Regional flow system (AR1)
— — — —	Flow system boundary
	Ground surface
▨	Area of observed flowing wells

R	Recharge area (downward flow)
D	Discharge area (upward flow)
x	Bottom of wells and piezometers
	Concealed fault
- - - - - - -	Hydrogeologic boundary
	HYDROGEOLOGIC UNITS
Qsg	Sand and gravel
Tpt	Phu Tok
Kms	Mahasaraham
rs	Rock salt
Kkk	Khok Kruat
Kpp	Phu Phan
Jpk	Phu Kraduang

Geomorphic parameters are defined in Figures 4.8 to 4.11

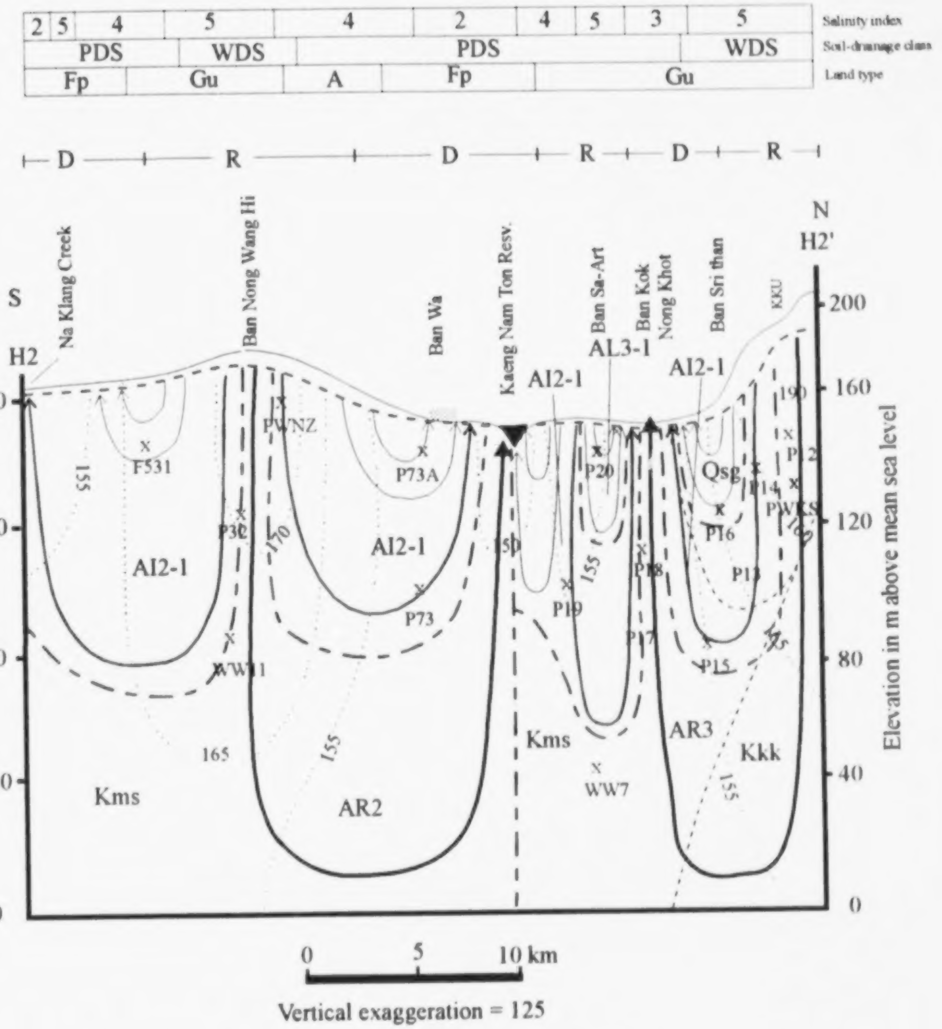

2 5 4 5 4 2 4 5 3 5
Salinity index
PDS WDS PDS WDS
Soil-drainage class
Fp Gu A Fp Gu
Land type
D R D R D R
S
H2
N
H2'
Na Klang Creek
Ban Nong Wang Hi
Ban Wa
Kaeng Nam Ton Resv.
Ban Sa-Art
Ban Kok Nong Khot
Ban Sri than
KKU
AI2-1
AL3-1
AI2-1
AI2-1
AI2-1
Qsg
F531
PWNZ
P73A
P32
P73
WW11
P20
P19
P18
P17
P16
P14
P12
PWKS
P13
P15
WW7
155
165
170
155
150
155
190
160
155
155
AR2
AR3
Kms
Kms
Kkk
0
40
80
120
160
200
Elevation in m above mean sea level
0 5 10 km
Vertical exaggeration = 125

Figure 4.3 Hydrogeologic profile H2 - H2'

160 Line of equal hydraulic head with elevation above mean sea level in m

Water table

Local flow system (AL1-1)

Intermediate flow system (AI1-1)

Regional flow system (AR1)

Flow system boundary

Geologic boundary

Area of observed flowing wells

Qsg Sand and gravel unit

Kms Mahasarakham unit

Kkk Khok Kruat unit

Ground surface

x Bottom of wells and piezometers

R Recharge areas (downward flow)

D Discharge areas (upward flow)

Geomorphic parameters are defined in Figures 4.8 to 4.11

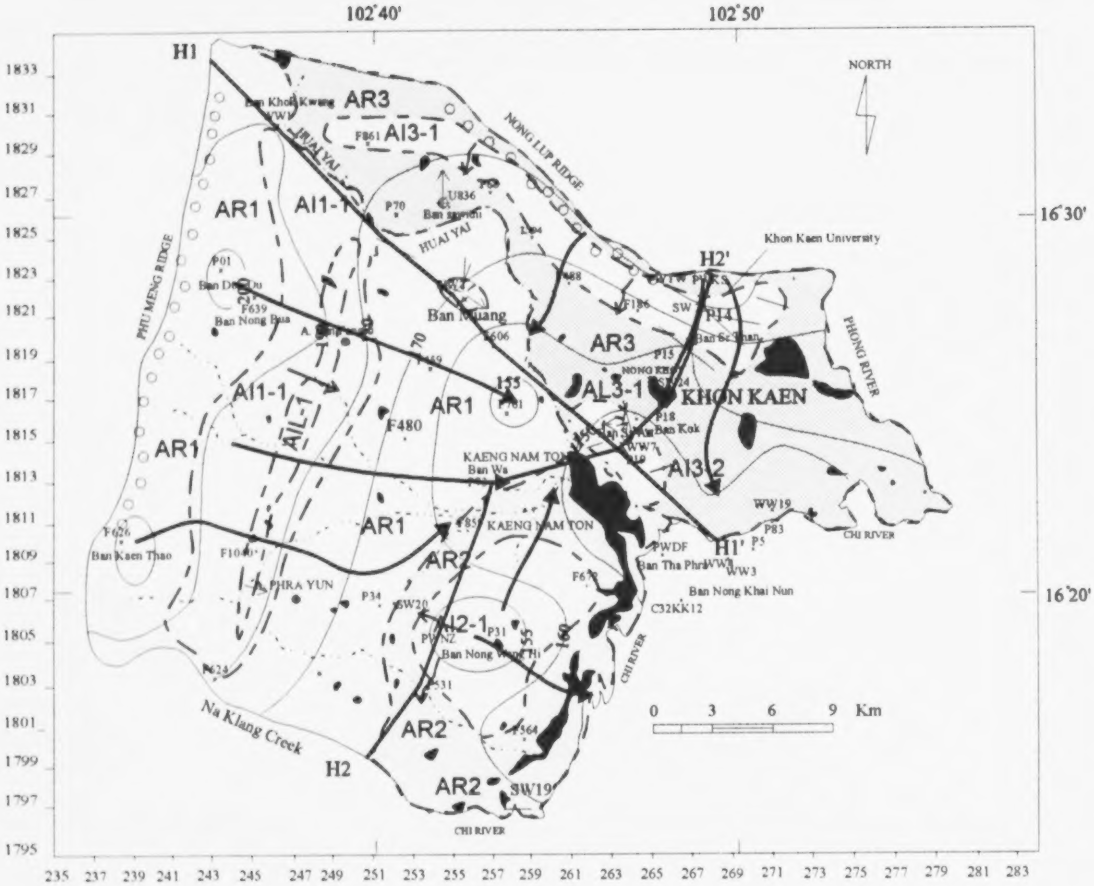

102°40'
102°50'
16°30'
16°20'
H1
H1'
H2
H2'
NORTH
AR1
AR2
AR3
AI1-1
AI3-1
AI3-2
AL3-1
AIL-1
AI2-1
KHON KAEN
KAENG NAM TON
PHU MENG RIDGE
NONG LUP RIDGE
PHONG RIVER
CHI RIVER
HUAI YAI
Na Klang Creek
Khon Kaen University
Ban Khok Kwang
Ban Muang
Ban Kaen Thao
Ban Nong Bua
Ban Tha Phra
Ban Nong Khai Nun
Ban Nong Wang Hi
PHRA YUN
Ban Kok
F480
F626
F639
F1040
P34
P31
SW20
SW19
WW19
WW3
P83
P5
PWDF
C32KK12
155
160
70
0 3 6 9 Km
1833
1831
1829
1827
1825
1823
1821
1819
1817
1815
1813
1811
1809
1807
1805
1803
1801
1799
1797
1795
235 237 239 241 243 245 247 249 251 253 255 257 259 261 263 265 267 269 271 273 275 277 279 281 283

Figure 4.4 Distribution of hydraulic heads, groundwater flow paths and flow systems in Huai Yai Hydrogeologic Province

Stream
Lake or reservoir
H —— H' Line of hydrogeologic profile
WW4 Water wells
P1and SW1 Piezometers and surfacewater
Surface and groundwater divide
160 Equipotential line
(10 m contour interval)
Flow path and direction
Local
Intermediate
Regional
Flow system boundary

Flow systems

	Regional
AR1	Phu Meng
AR2	Nong Wang Hi
AR3	Nong Lup
	Intermediate
AI1-1	Ban Khok Kwang
AI2-1	Ban Kham Pom
AI3-1	Ban Sri Than
AI3-2	Kaeng Nam Ton
	Local
AL1-1	Ban Fang
AL1-2	Ban Muang
AL2-1	Ban Nong Wang Hi
AL3-1	Ban Sa Art

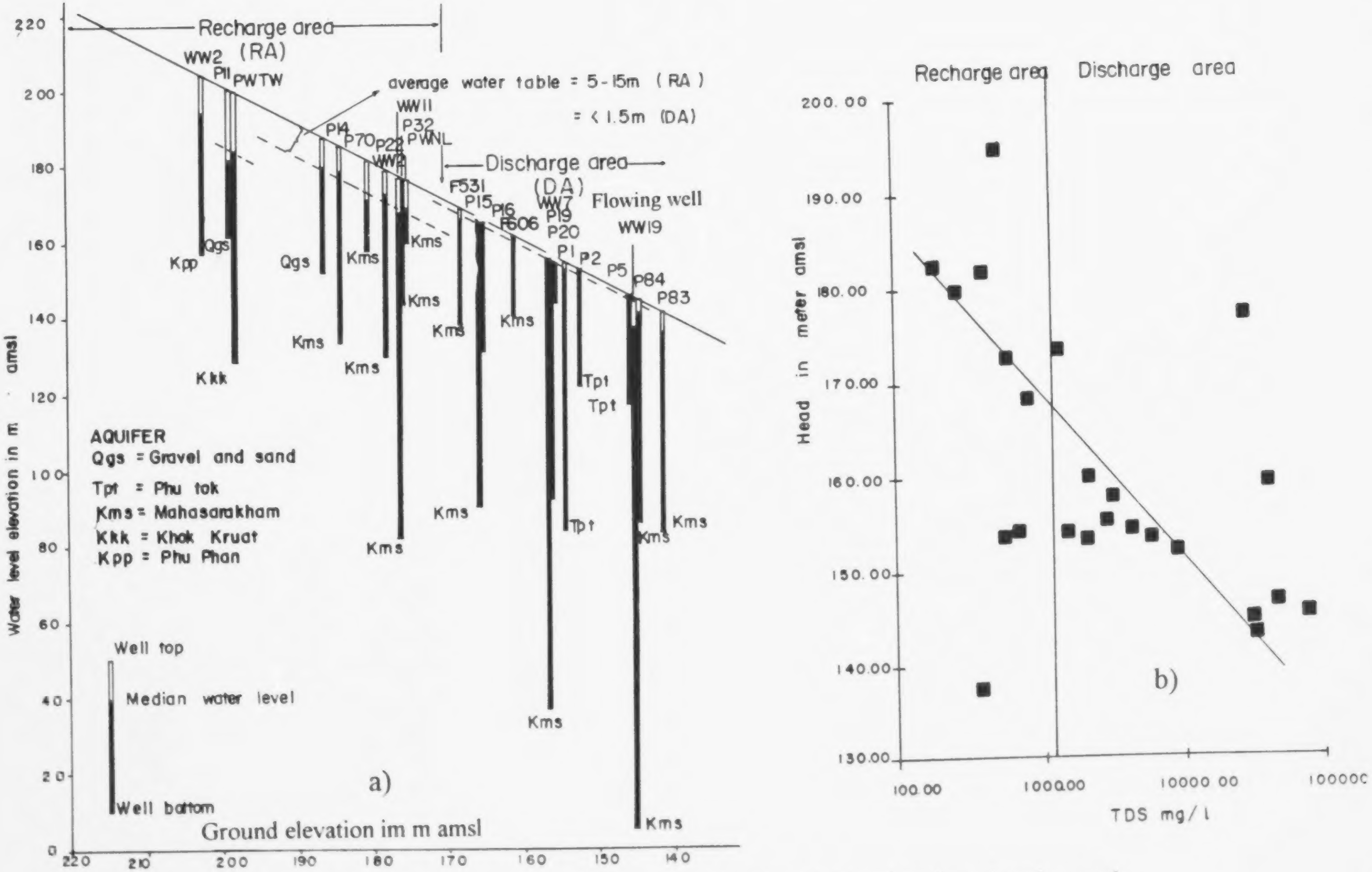


Figure 4.5 Relationship between a) well depts, water levels and ground surface elevations and b) Total dissolved solids and hydraulic heads in Huai Yai Hydrogeologic Province

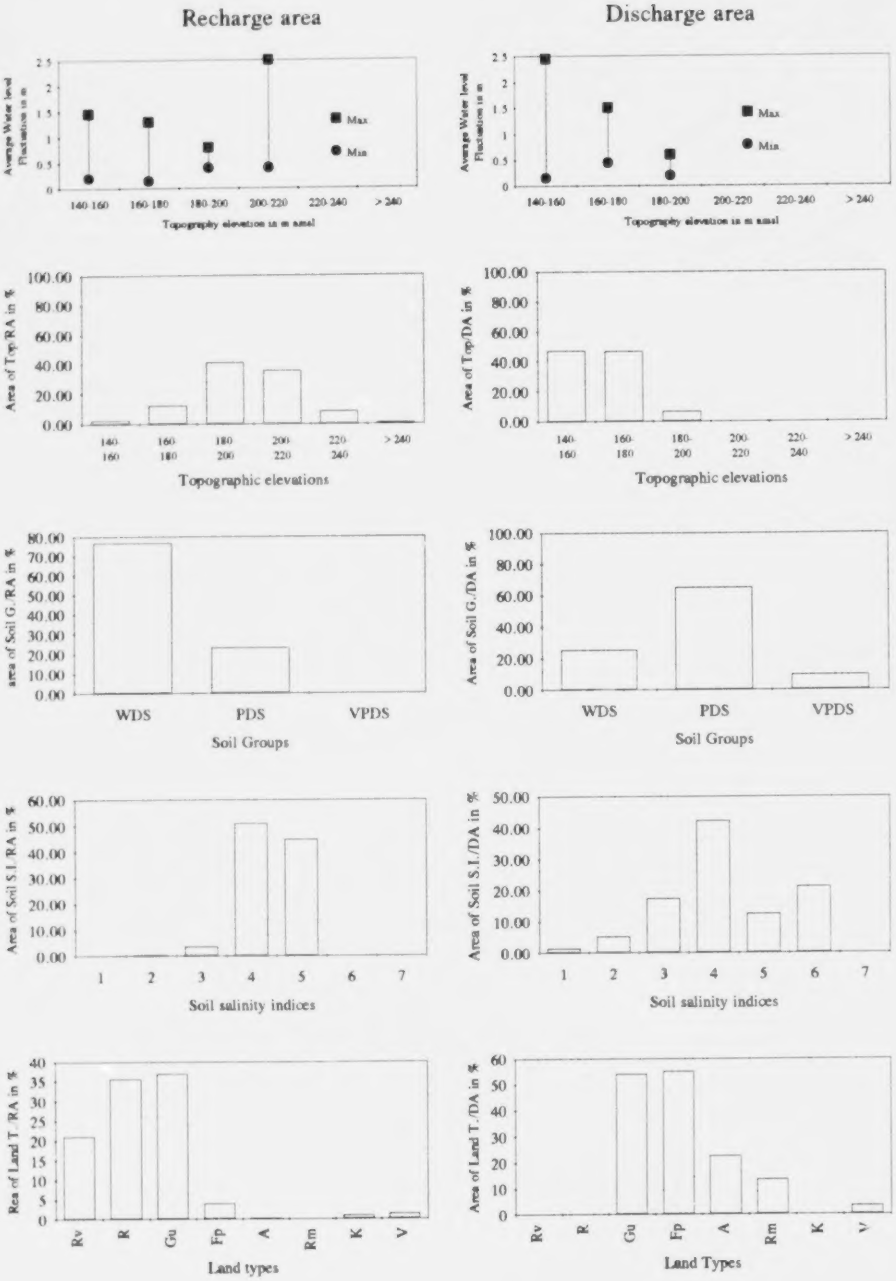


Figure 4.6 Relationship between recharge and discharge areas, water level fluctuations, topographic elevations, soil-drainage classes, soil salinity indices, and land types in Huai Yai Hydrogeologic Province

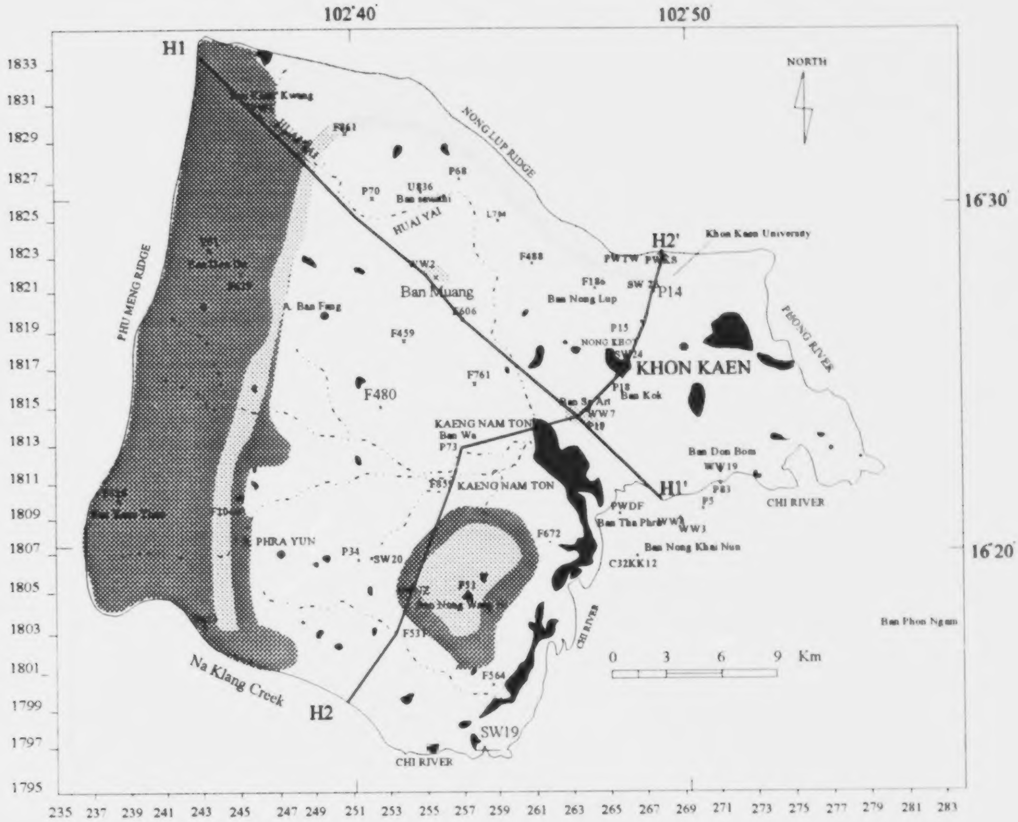

102°40'
102°50'
16°30'
16°20'
NORTH
H1
H1'
H2
H2'
PHU MENG RIDGE
NONG LUP RIDGE
HUAI YAI
PHONG RIVER
CHI RIVER
Na Klang Creek
Ban Muang
KHON KAEN
KAENG NAM TON
PHRA YUN
Khon Kaen University
Ban Nong Lup
Ban Kok
Ban Don Bom
Ban Tha Phra
Ban Nong Khai Nun
Ban Phon Ngam
A. Ban Fang
P70
P68
F461
F488
F459
F480
F761
F606
F672
F531
F564
P14
P15
P18
P19
P73
P34
P5
P83
SW19
SW20
SW24
WW2
WW3
WW7
WW19
PWDF
PWTW
C32KK12
0 3 6 9 Km
1833
1831
1829
1827
1825
1823
1821
1819
1817
1815
1813
1811
1809
1807
1805
1803
1801
1799
1797
1795
235 237 239 241 243 245 247 249 251 253 255 257 259 261 263 265 267 269 271 273 275 277 279 281 283

Figure 4.7 Distribution of recharge rates estimated by water level fluctuation in Huai Yai Hydrogeologic Province

	Stream
	Lake or reservoir
H1____ H1'	Line of hydrogeological profile
●	Amphoe or district
WW1	Water wells
P20 & SW22	Piezometers and surface water

Recharge rate in m/s (E-09)

☐	0.01 -2.00
☐	2.00 - 5.00
▨	5.00 - 10.00
■	10.00 - 20.00
	Hydrogeologic province boundary

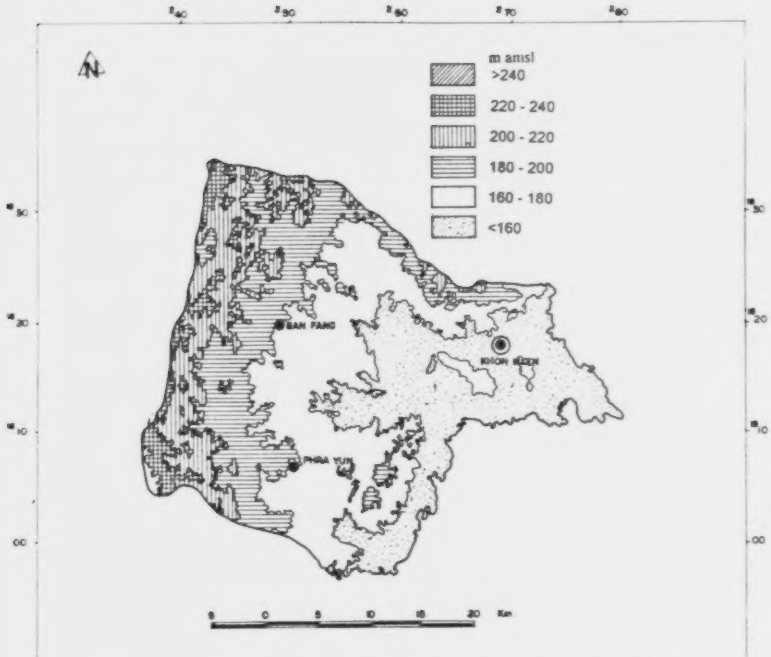

N
m amsl
>240
220 - 240
200 - 220
180 - 200
160 - 180
<160
BAN FANG
KHON KAEN
PHRA YUN
5 0 5 10 15 20 Km

Figure 4.8 Topographic map of Huai Yai hydrogeologic province

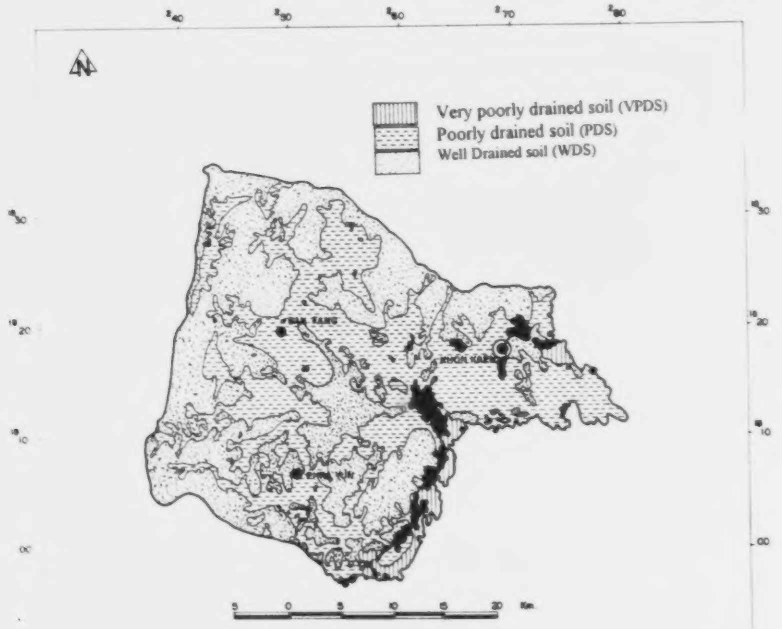

N
Very poorly drained soil (VPDS)
Poorly drained soil (PDS)
Well Drained soil (WDS)
BAN FANG
KHON KAEN
PHRA YUN
5 0 5 10 15 20 Km

Figure 4.9 Soil-drainage class of Huai Yai Hydrogeologic Province (modified from Soil Survey Division, 1973a)

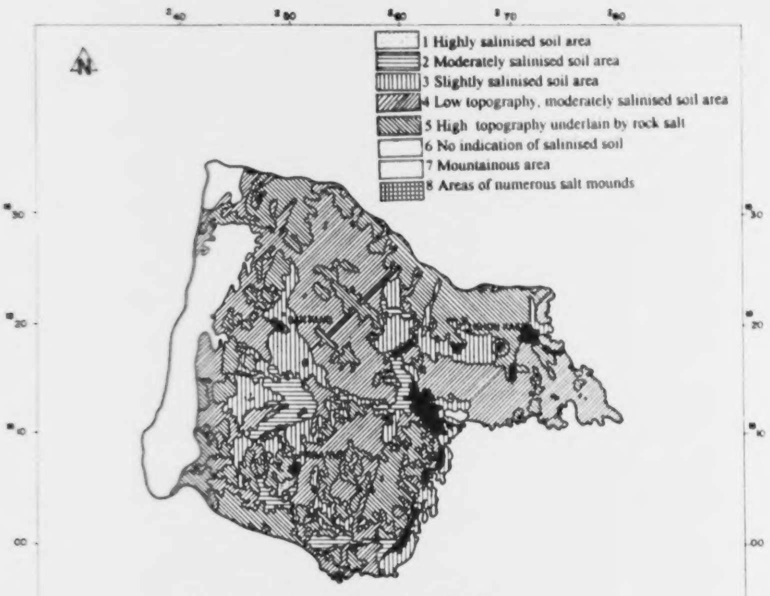

N
1 Highly salinised soil area
2 Moderately salinised soil area
3 Slightly salinised soil area
4 Low topography, moderately salinised soil area
5 High topography underlain by rock salt
6 No indication of salinised soil
7 Mountainous area
8 Areas of numerous salt mounds
KHON KAEN
5 0 5 10 15 20 Km

Figure 4.10 Soil salinity map of Huai Yai Hydrogeologic Province (modified from Soil Survey Division, 1973a)

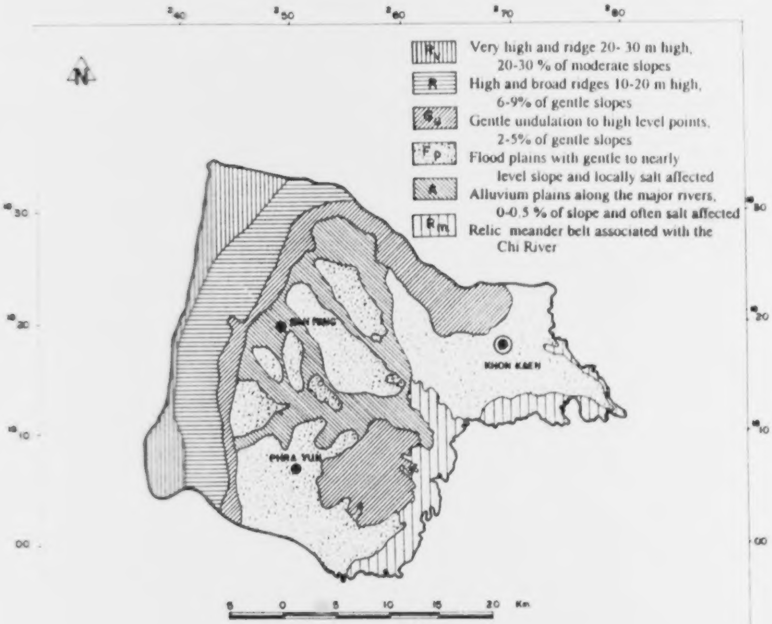

N
Rh
Very high and ridge 20- 30 m high, 20-30 % of moderate slopes
R
High and broad ridges 10-20 m high, 6-9% of gentle slopes
Gu
Gentle undulation to high level points, 2-5% of gentle slopes
Fp
Flood plains with gentle to nearly level slope and locally salt affected
A
Alluvium plains along the major rivers, 0-0.5 % of slope and often salt affected
Rm
Relic meander belt associated with the Chi River
BAN FANG
KHON KAEN
PHRA YUN
5 0 5 10 15 20 Km

Figure 4.11 Land type map of Huai Yai Hydrogeologic Province

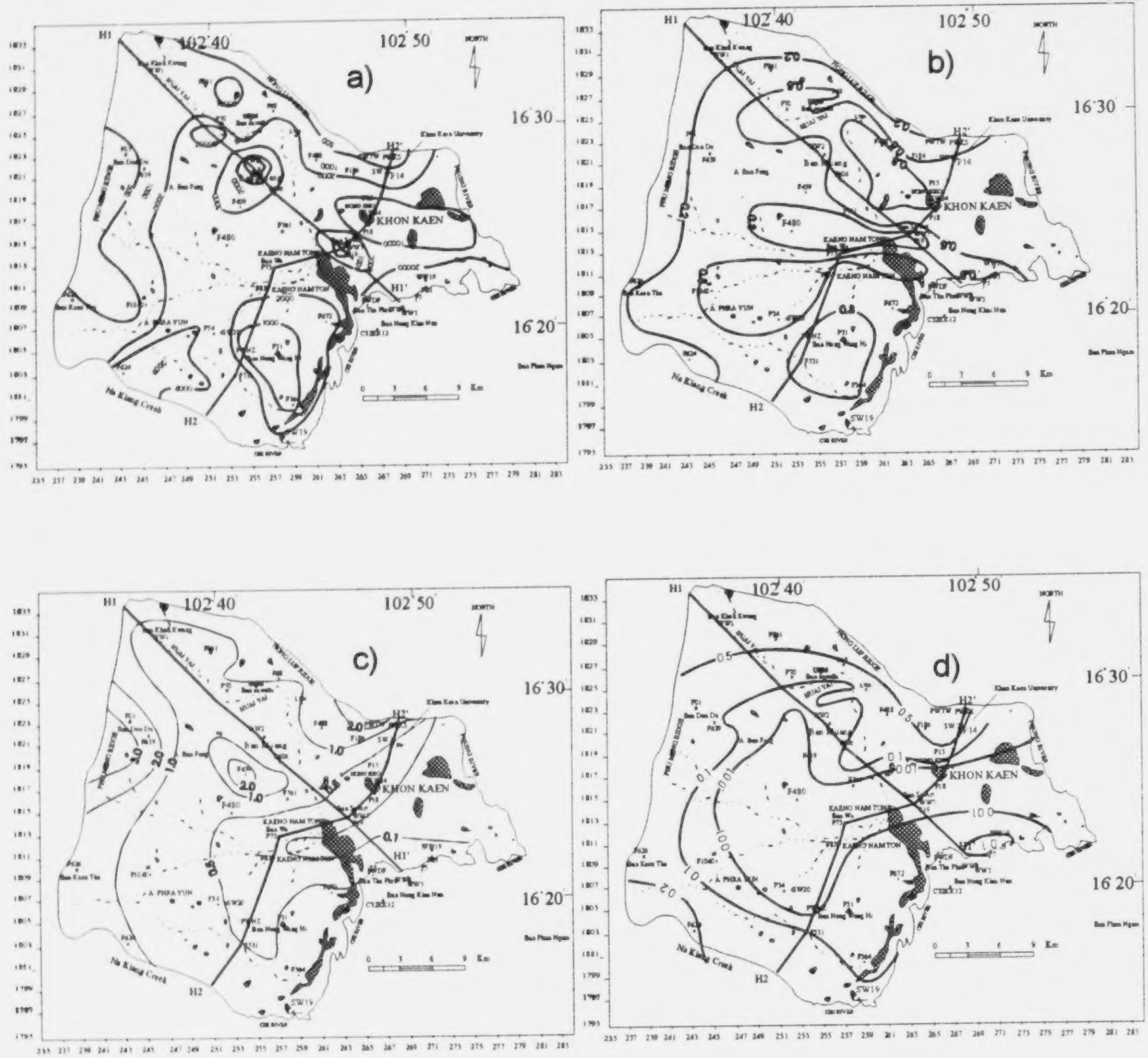

a)
b)
c)
d)
H1
H1'
H2
H2'
102°40
102°50
16°30
16°20
KHON KAEN
KAENG NAM TON
A. PHRA YUN
Khon Kaen University
Na Klang Creek
SW19
F480
NORTH
0 3 6 9 Km

Figure 4.12 Distribution of TDS and ionic ratios in Huai Yai Hydrogeologic Province

a) TDS contents (mg/l)
b) magnesium to calcium ratio
c) calcium to sodium ratio
d) sulphate to chloride ratio

- · - ·	Stream
▨	Lake or reservoir
H1 ___H1'	Line of hydrogeological profile
	Amphoe or district
WW2	Water wells
P01 & SW2	Piezometers and surfacewater
1000	TDS in mg/l

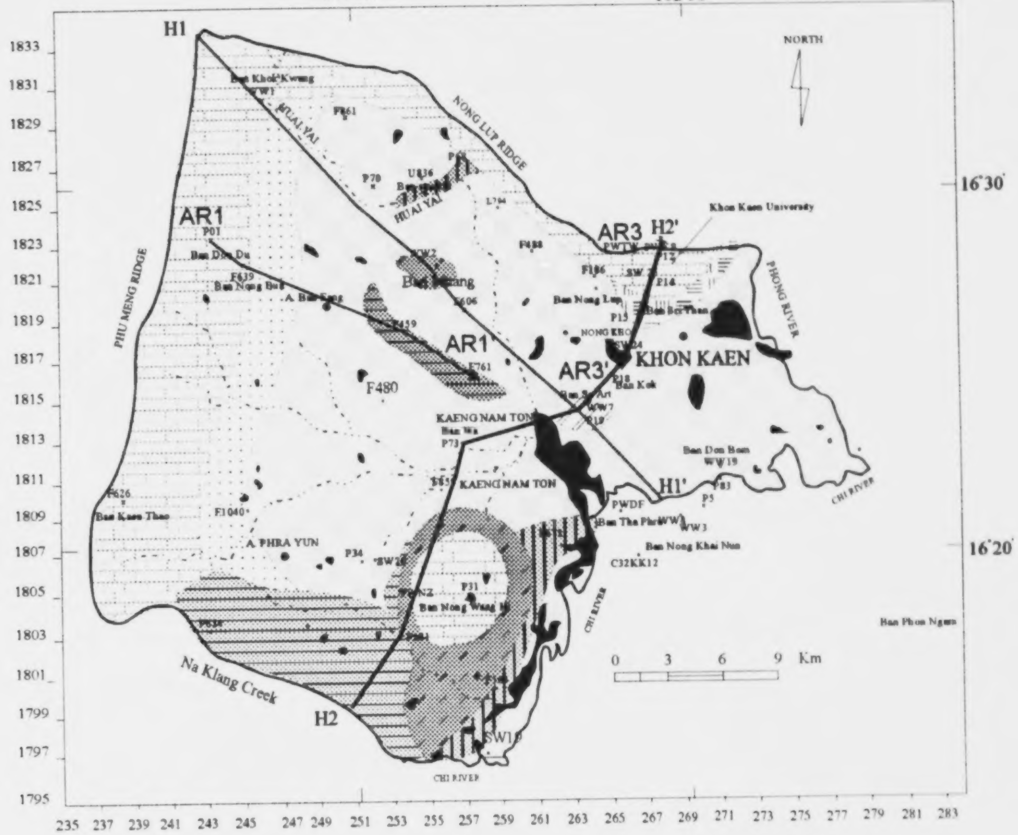

102°40'
102°50'
16°30'
16°20'
NORTH
H1
H1'
H2
H2'
AR1
AR1'
AR3
AR3'
KHON KAEN
Khon Kaen University
KAENG NAM TON
A. PHRA YUN
NONG KHO
PHU MENG RIDGE
NONG LUP RIDGE
HUAI YAI
PHONG RIVER
CHI RIVER
Na Klang Creek
F480
P01
SW19
0 3 6 9 Km
1833
1831
1829
1827
1825
1823
1821
1819
1817
1815
1813
1811
1809
1807
1805
1803
1801
1799
1797
1795
235 237 239 241 243 245 247 249 251 253 255 257 259 261 263 265 267 269 271 273 275 277 279 281 283

Figure 4.13 Distribution of hydrochemical facies in Huai Yai Hydrogeologic Province

Stream

Lake or reservoir

H1____ H1' Line of hydrogeological profile

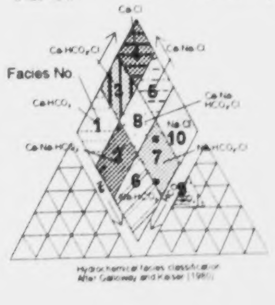
Amphoe or district

WW2 Water wells

P01 & SW2 Piezometers and surfacewater

AR3 ⟶ AR3' Flow path for determing hydrochemical processes

Hydrochemical facies	Average TDS in mg/l
Ca-HCO3	448
Ca-Na-HCO3	668
Na-HCO3	432
Ca-HCO3-Cl	160-1300
Ca-Cl	3300
Ca-Na-HCO3-Cl	431
Na-SO4-Cl	2100-43000
Na-Cl	1600-75,000


Ca Cl
Ca HCO3-Cl
Ca Na Cl
Facies No
Ca HCO3
Ca Na HCO3-Cl
Na Cl
Ca Na HCO3
Na HCO3-Cl
Na HCO3
1
2
4
5
6
7
8
10

Hydrochemical facies classification After Galloway and Kaiser (1980)

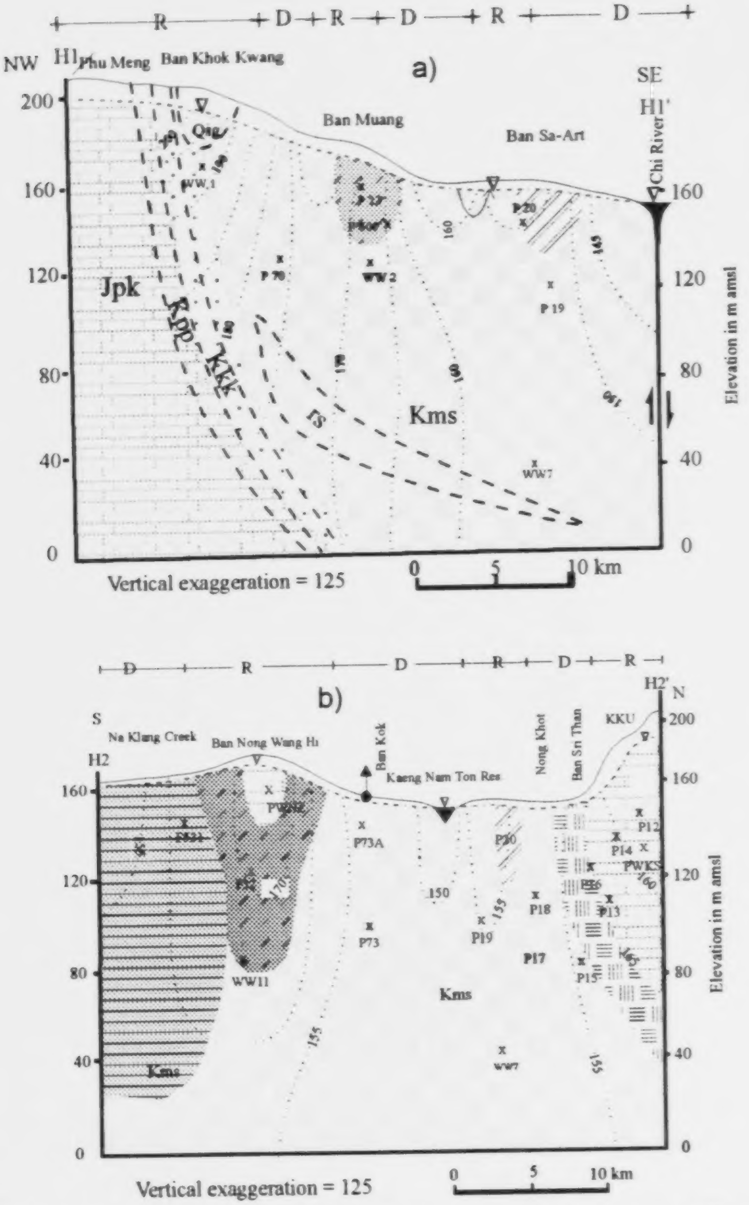

R D R D R D
a)
NW
H1
Phu Meng
Ban Khok Kwang
SE
H1'
Chi River
Ban Muang
Ban Sa-Art
Qa
WW1
P27
P70
WW2
P20
P19
WW7
Jpk
Kpp
Kkk
Kms
160
155
150
145
200
160
120
80
40
0
Elevation in m amsl
Vertical exaggeration = 125
0 5 10 km
D R D R D R
b)
S
H2
Na Klang Creek
Ban Nong Wang Hi
Ban Kok
Kaeng Nam Ton Res
Nong Khot
Ban Sn Than
KKU
H2'
N
PWNH
P73A
P73
WW11
P30
P19
P18
P17
P12
P14
PWKS
P13
P15
WW7
Kms
150
155
160
Vertical exaggeration = 125
0 5 10 km

Figure 4.14 Hydrochemical facies along hydrogeologic profiles
a) H1-H1' and b) H2-H2'

··· 160 ··· Line of equal hydraulic heads with elevation above mean sea level in m
--- --- Water table
x Bottom of wells and piezometers
Ground surface
Area of observed flowing wells
R Recharge area
D Discharge area
Concealed fault
- - - Hydrogeologic boundary

Hydrochemical facies
Ca-HCO3
Ca-Na-HCO3
Na-HCO3
Ca-HCO3-Cl
Ca-Cl
Ca-Na-HCO3-Cl
Na-SO4-Cl
Na-Cl

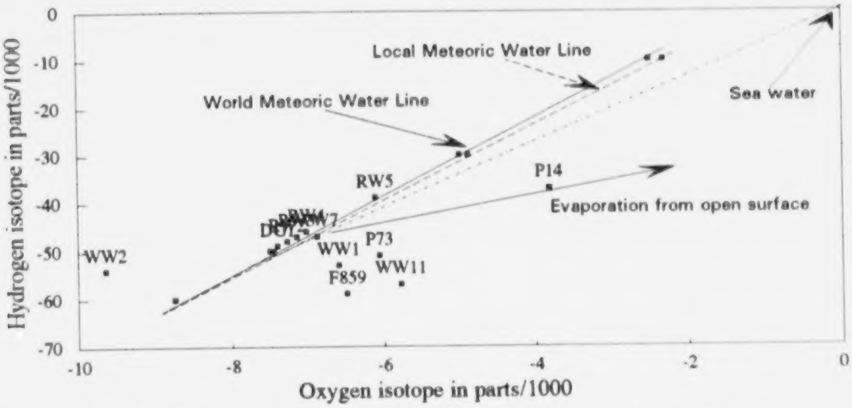


Figure 4.15 Relationship of concentrations for hydrogen and oxygen isotopes in Huai Yai Hydrogeologic Province

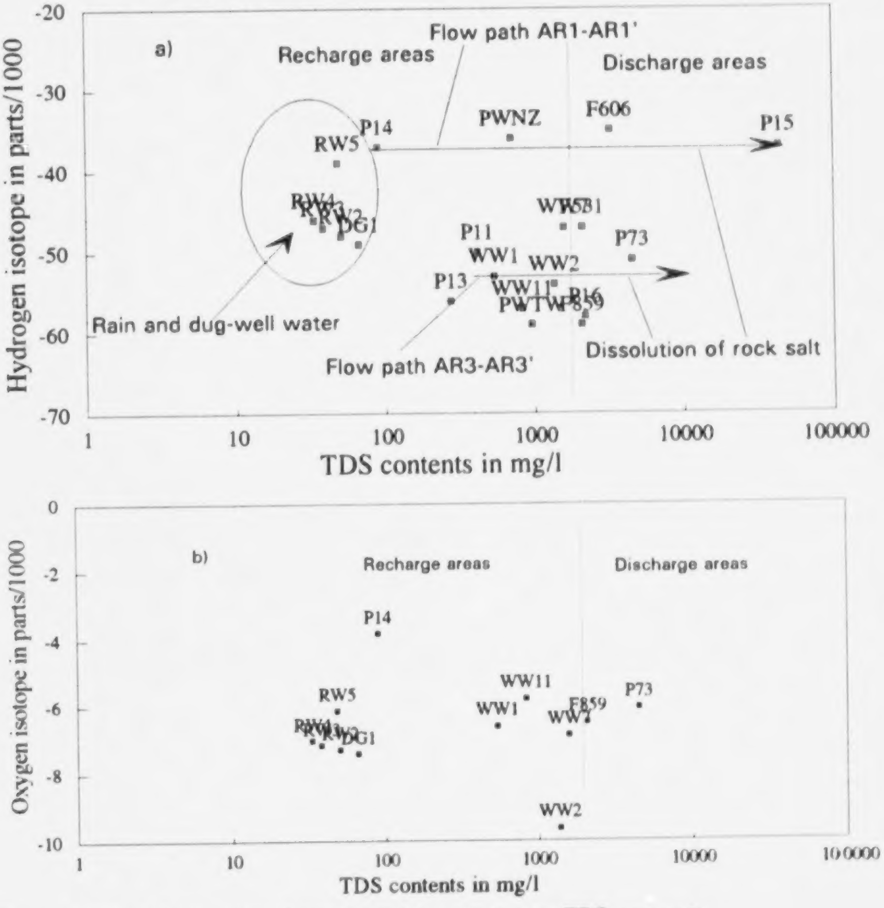


Figure 4.16 Relationship of concentrations between TDS contents and hydrogen (a) and oxygen isotopes (b) in Huai Yai Hydrogeologic Province

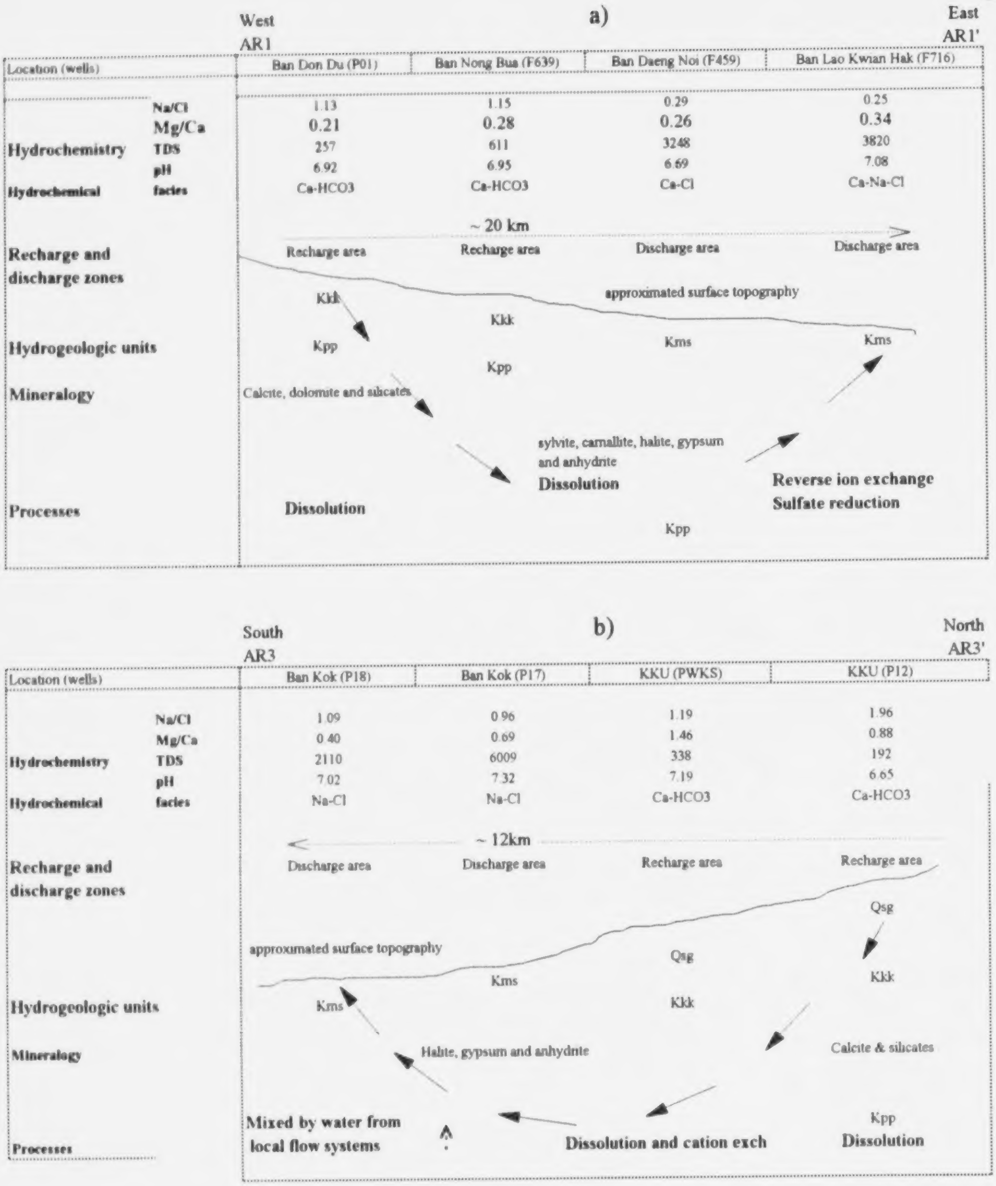

a)
West
AR1
East
AR1'
Location (wells)
Ban Don Du (P01)
Ban Nong Bua (F639)
Ban Daeng Noi (F459)
Ban Lao Kwian Hak (F716)
Hydrochemistry
Na/Cl
1.13
1.15
0.29
0.25
Mg/Ca
0.21
0.28
0.26
0.34
TDS
257
611
3248
3820
pH
6.92
6.95
6.69
7.08
Hydrochemical facies
Ca-HCO3
Ca-HCO3
Ca-Cl
Ca-Na-Cl
~ 20 km
Recharge and discharge zones
Recharge area
Recharge area
Discharge area
Discharge area
approximated surface topography
Hydrogeologic units
Kkk
Kpp
Kkk
Kpp
Kms
Kms
Kpp
Mineralogy
Calcite, dolomite and silicates
sylvite, carnallite, halite, gypsum and anhydrite
Processes
Dissolution
Dissolution
Reverse ion exchange
Sulfate reduction
b)
South
AR3
North
AR3'
Location (wells)
Ban Kok (P18)
Ban Kok (P17)
KKU (PWKS)
KKU (P12)
Hydrochemistry
Na/Cl
1.09
0.96
1.19
1.96
Mg/Ca
0.40
0.69
1.46
0.88
TDS
2110
6009
338
192
pH
7.02
7.32
7.19
6.65
Hydrochemical facies
Na-Cl
Na-Cl
Ca-HCO3
Ca-HCO3
~ 12km
Recharge and discharge zones
Discharge area
Discharge area
Recharge area
Recharge area
approximated surface topography
Hydrogeologic units
Qsg
Qsg
Kkk
Kms
Kms
Kkk
Mineralogy
Halite, gypsum and anhydrite
Calcite & silicates
Processes
Mixed by water from local flow systems
Dissolution and cation exch
Kpp
Dissolution

Figure 4.17 Schematic diagram showing hydrochemical processes along
a) AR1-AR1' flow path for Phu Meng regional flow system (CR1)
b) AR3-AR3' flow path for Nong Lup regional flow system (CR3)
in Huai Yai Hydrogeologic Province

→ Flow line

Qsg = Sand and gravel unit

Kms = Mahasarakham unit

Kkk = Khok Kruat unit

Kpp = Phu Phan unit

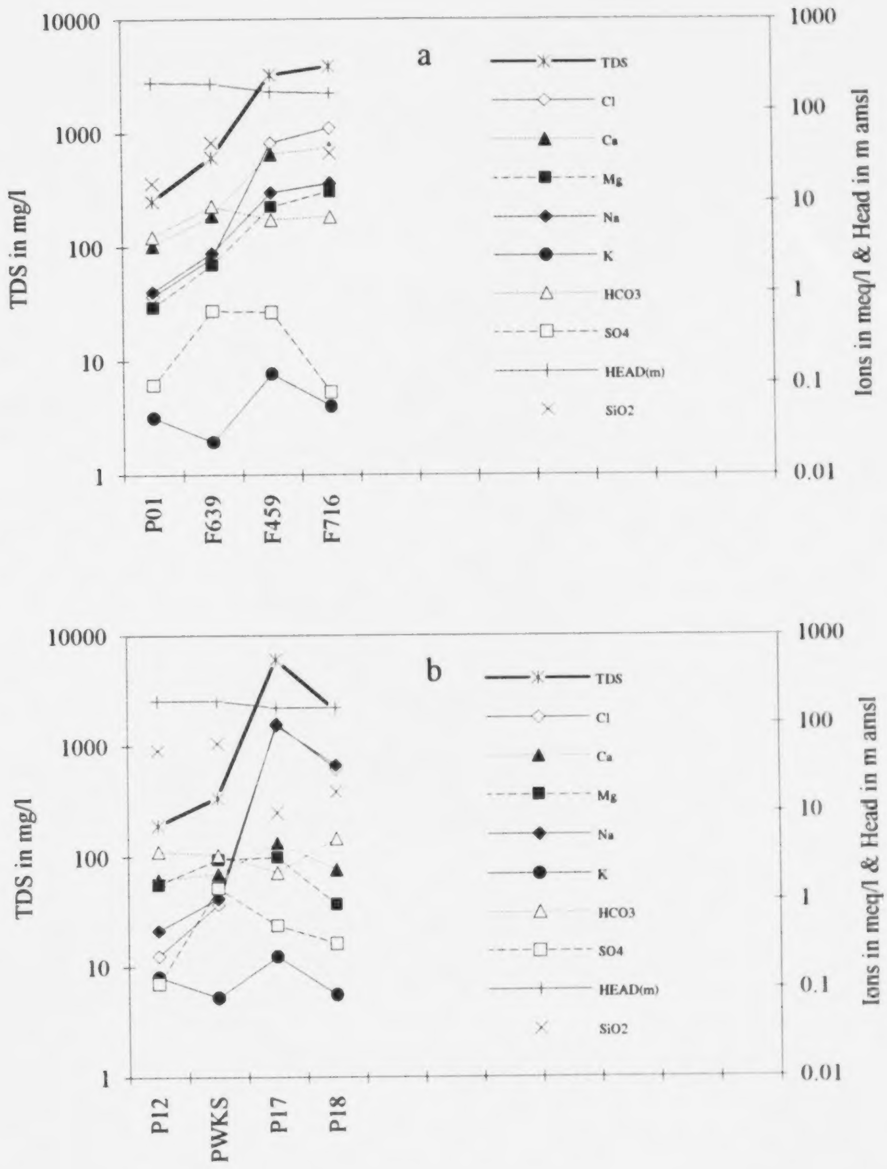


Figure 4.18 Concentrations of individual major ions for selected flow paths
a) for Phu Meng regional flow system (AR1) and
b) for Nong Lup regional flow system (AR3)
in Huai Yai Hydrogeologic Province

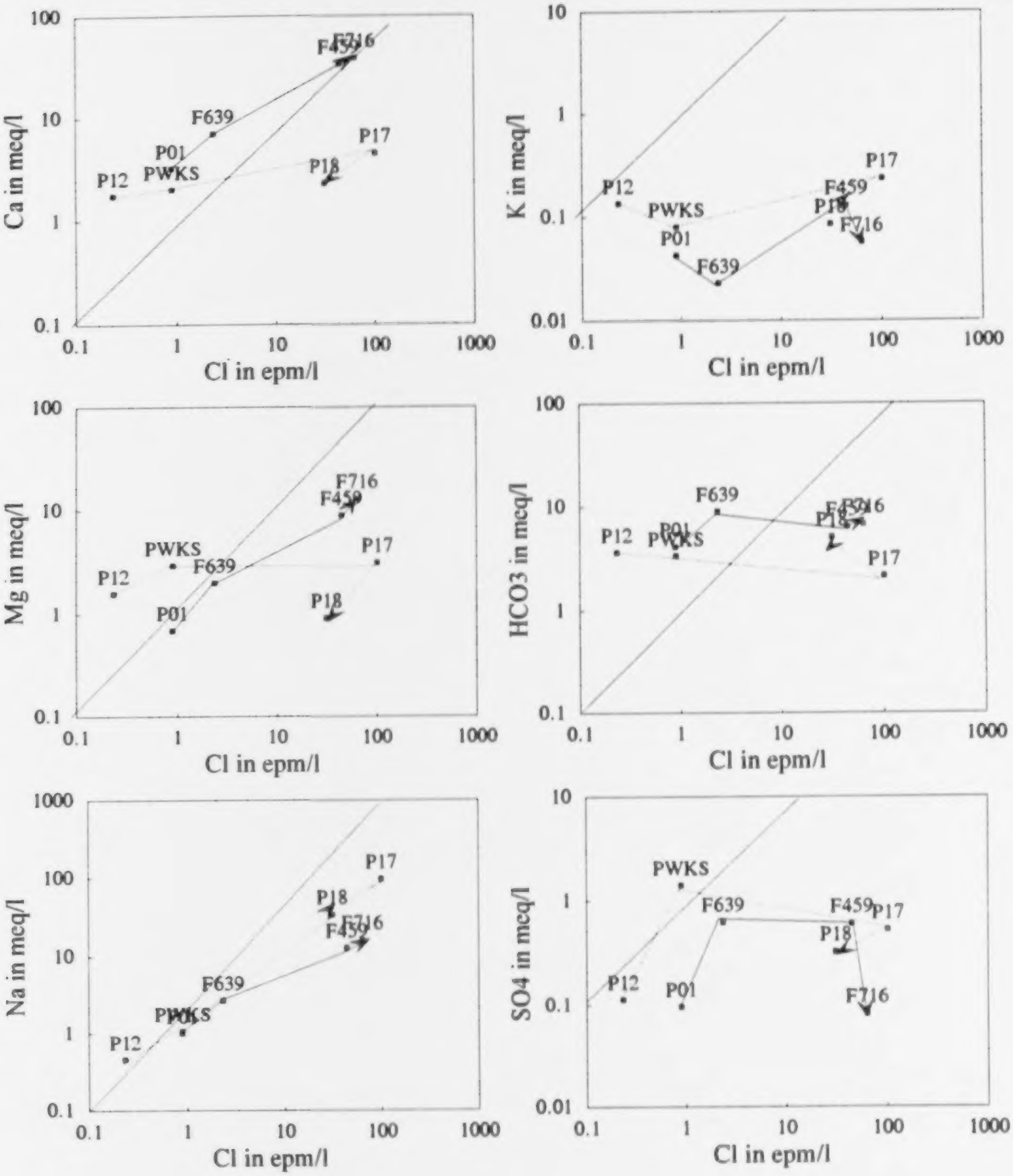


Figure 4.19 Concentrations of individual major ions related to chloride ion for selected flow paths in Huai Yai Hydrogeologic Province
Phu Meng regional system (AR1) = solid line
Nong Lup regional system (AR3) = dash line

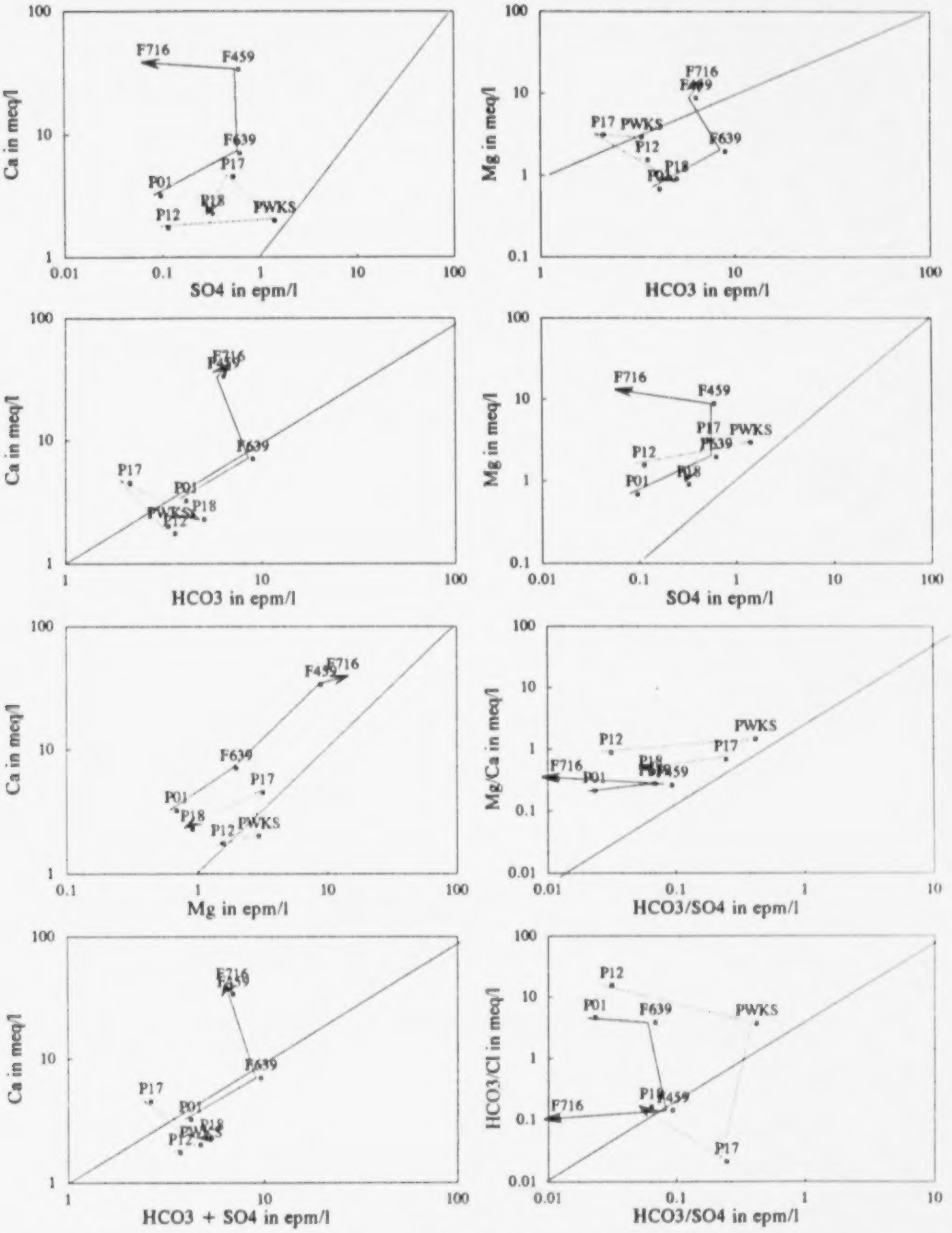


Figure 4.20 Relationship of ionic parameters for selected regional groundwater flow syste
in Huai Yai Hydrogeologic Province
Phu Meng regional system (AR1) = solid line
Nong Lup regional system (AR3) = dash line

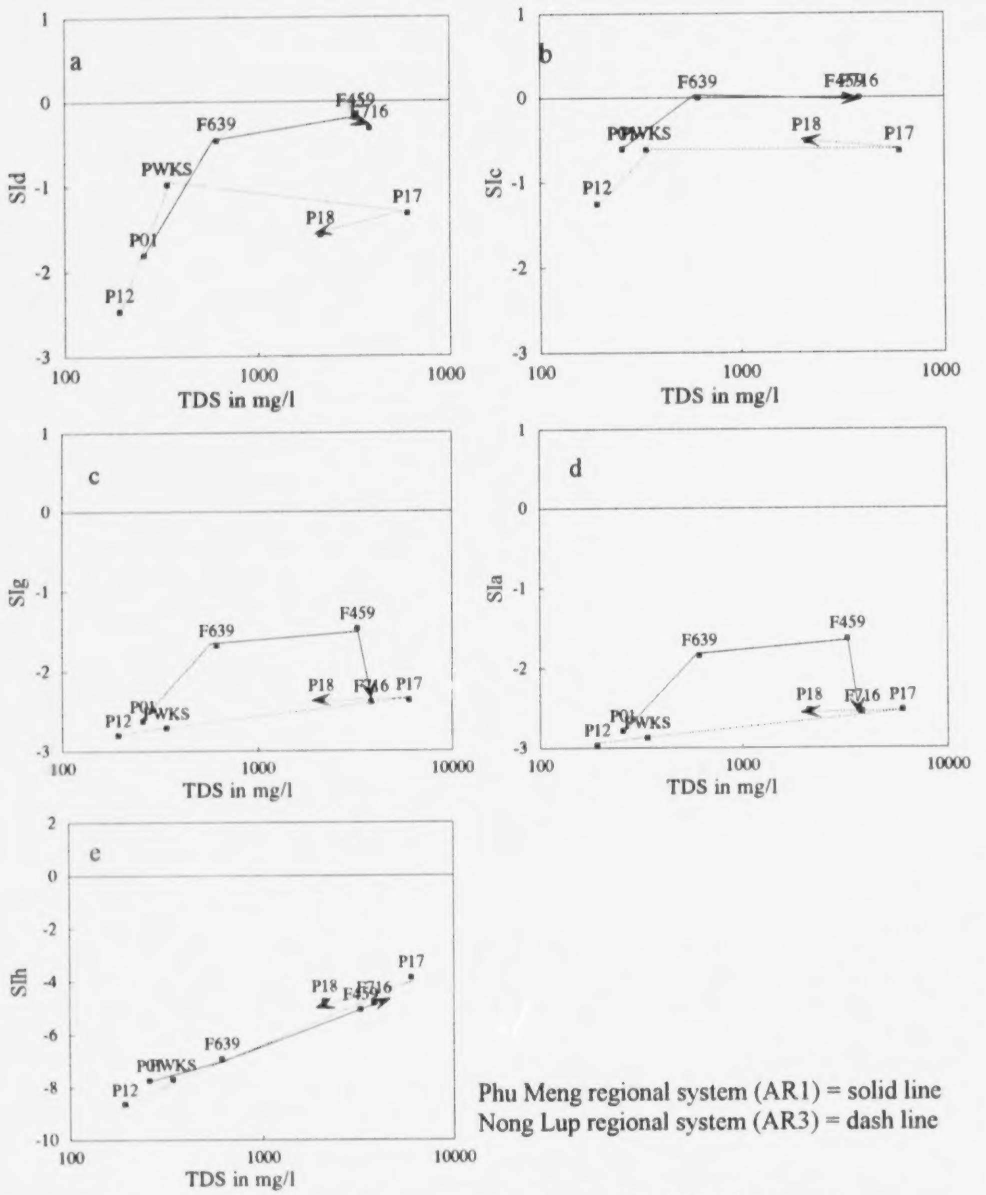


Figure 4.21 Saturation indices with respect to a) dolomite, b) calcite, c) gypsum, d) anhydrite and e) halite, as a function of TDS contents in groundwater along the flow paths in Huai Yai Hydrogeologic Province

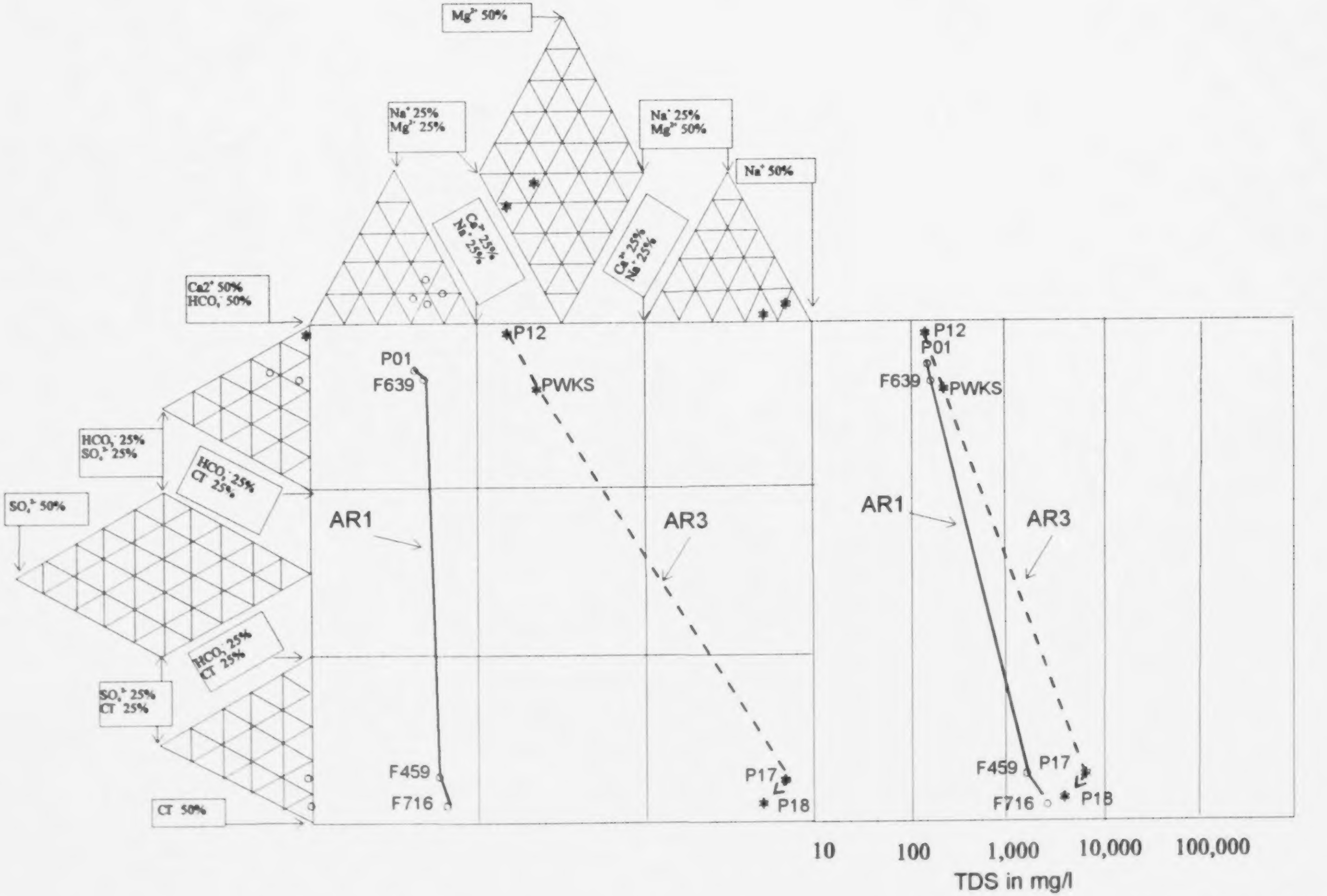


Figure 4.22 Expanded Durov diagram of selected groundwater samples along the flow paths AR1 and AR3 in Huai Yai Hydrogeologic Province

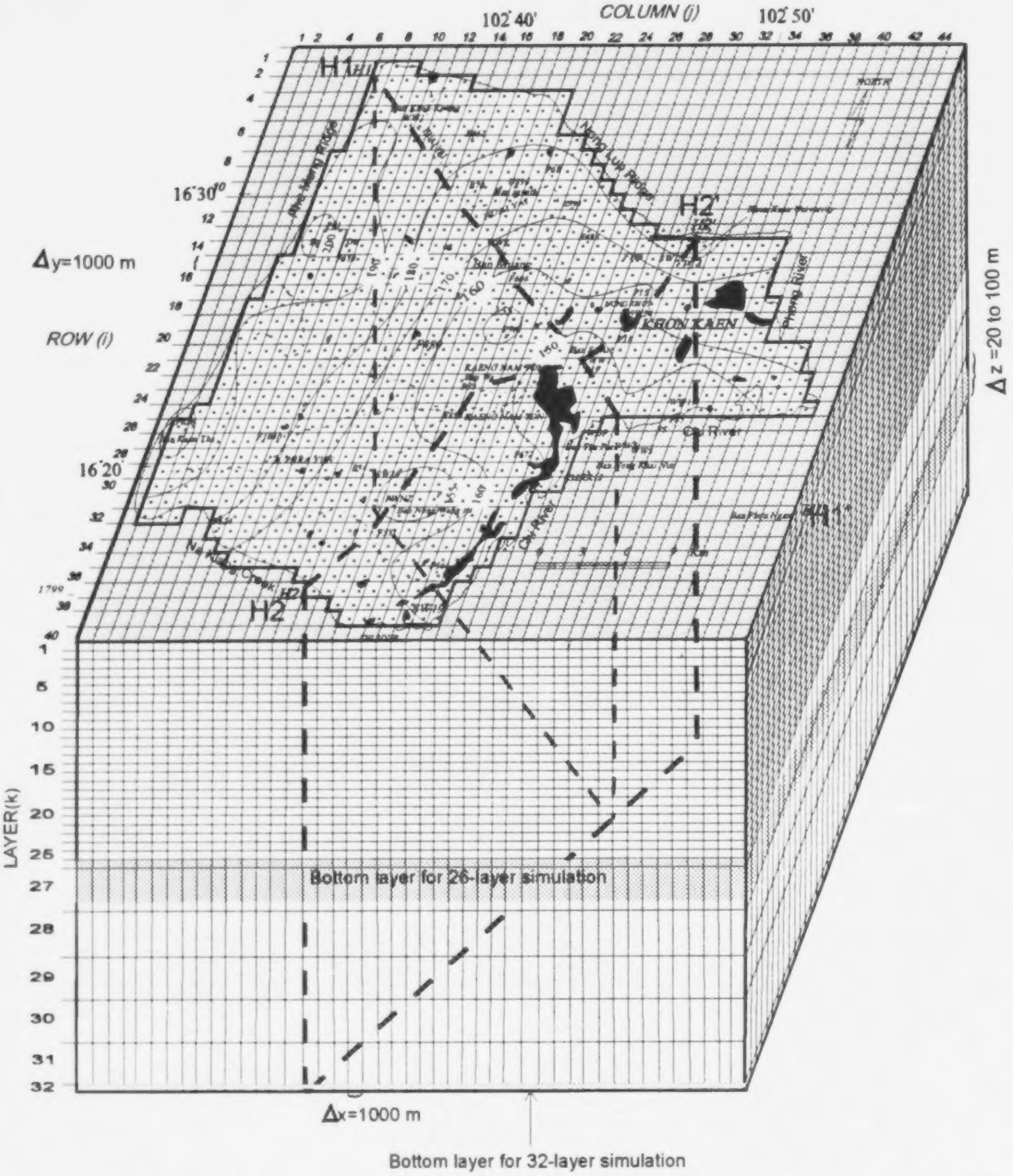

102°40'
COLUMN (j)
102°50'
H1
H2'
H2
16°30'
16°20'
Δy=1000 m
ROW (i)
Δz =20 to 100 m
KHON KAEN
Chi River
LAYER(k)
Bottom layer for 26-layer simulation
Δx=1000 m
Bottom layer for 32-layer simulation

Figure 4.23 Schematic diagram of a full three-dimensional model for Huai Yai Hydrogeologic Province and distribution of measured hydraulic heads

	Stream
	Lake or reservoir
H1 —— H1'	Line of hydrogeological profile
WW1	Water wells
P20 & SW22	Piezometers and surfacewater
	Model boundary
⊡	Block-centered grid for active cell
☐	Incative cell

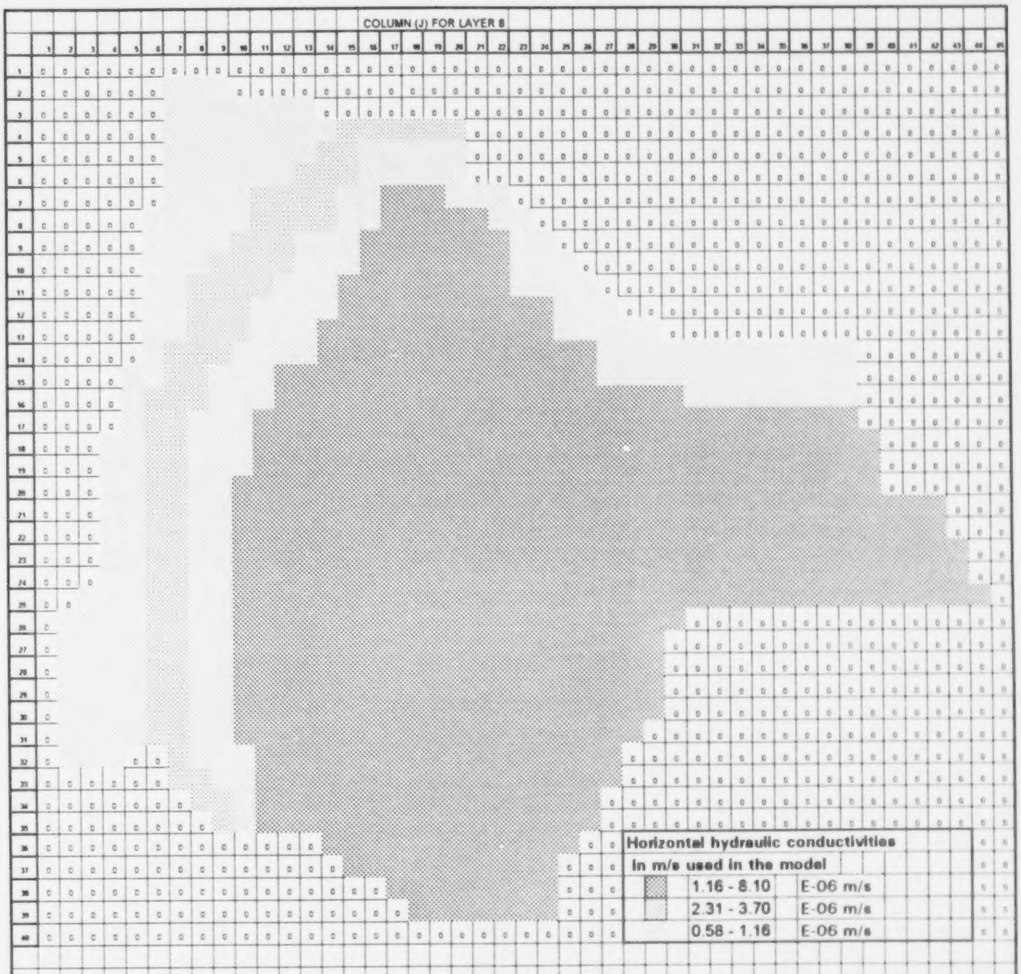

COLUMN (J) FOR LAYER 8
Horizontal hydraulic conductivities
in m/s used in the model
▨ 1.16 - 8.10 E-06 m/s
░ 2.31 - 3.70 E-06 m/s
0.58 - 1.16 E-06 m/s

Figure 4.24a Final input assigned horizontal conductivities of aquifers and aquitards of Huai Yai Hydrogeologic Province formodel layer 8

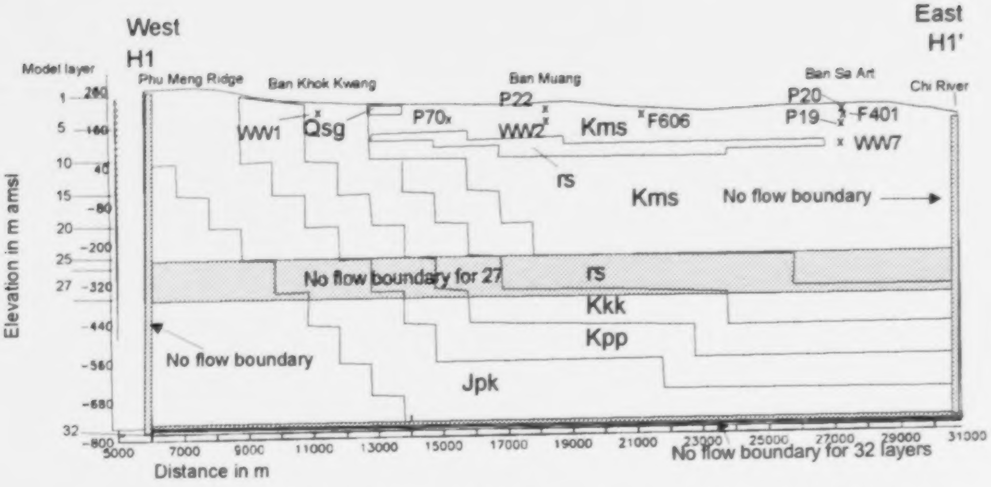

West
H1
East
H1'
Model layer
Phu Meng Ridge
Ban Khok Kwang
Ban Muang
Ban Sa Art
Chi River
P22
P20
P19
F401
WW1
Qsg
P70
WW2
Kms
F606
WW7
rs
Kms
No flow boundary
No flow boundary for 27
rs
Kkk
Kpp
No flow boundary
Jpk
Elevation in m amsl
1
5
10
15
20
25
27
32
200
160
40
-80
-200
-320
-440
-560
-680
-800
5000
7000
9000
11000
13000
15000
17000
19000
21000
23000
25000
27000
29000
31000
Distance in m
No flow boundary for 32 layers

Figure4.24b Final adjusted horizontal and vertical hydraulic conductivites of aquifers and aquitards for Huai Yai Hydrogeologic Province along H1-H1'

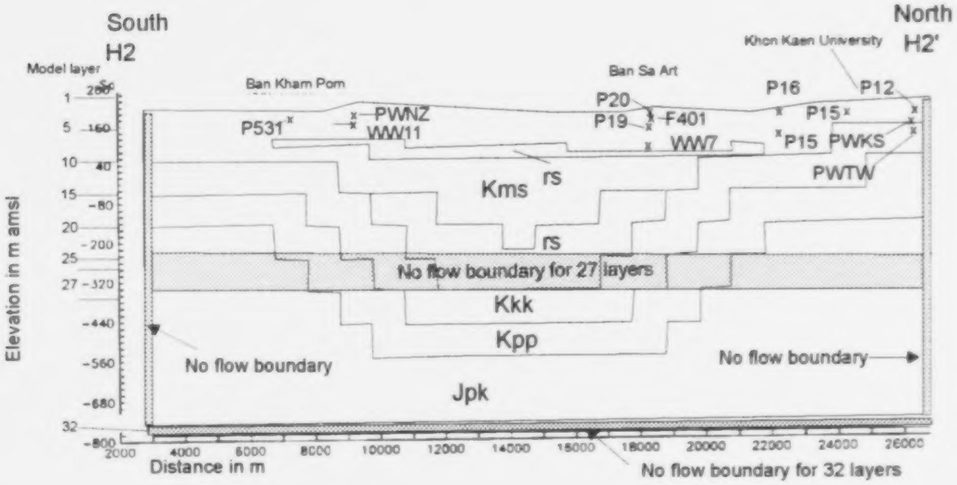

South
H2
North
H2'
Model layer
Khon Kaen University
Ban Sa Art
Ban Kham Pom
P20
P19
F401
P16
P12
P15
P531
PWNZ
WW11
WW7
P15
PWKS
PWTW
rs
Kms
rs
No flow boundary for 27 layers
Kkk
Kpp
No flow boundary
No flow boundary
Jpk
Elevation in m amsl
1
5
10
15
20
25
27
32
200
160
40
-80
-200
-320
-440
-560
-680
-800
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
Distance in m
No flow boundary for 32 layers

Figure4.24c Final adjusted horizontal and vertical hydraulic conductivites of aquifers and aquitards for Huai Yai Hydrogeologic Province along H2-H2'

Hydrogeologic unit	Kx = Ky m/s ($x10^{-6}$)	Kz m/s ($x10^{-6}$)	Kx/Kz
Qsg	11.6-25.5	1.16-6.94	10.0-3.7
Kms	1.16-8.10	0.11-0.58	10.0-14.0
Kkk	0.11-0.58	0.01-0.11	1.0-50.0
rs	0.01-0.05	0.01-0.05	1.0
Kpp	2.31-3.70	2.31-0.11	1.0-32.0
Jpk	0.11-0.57	0.11	1.0-5.0

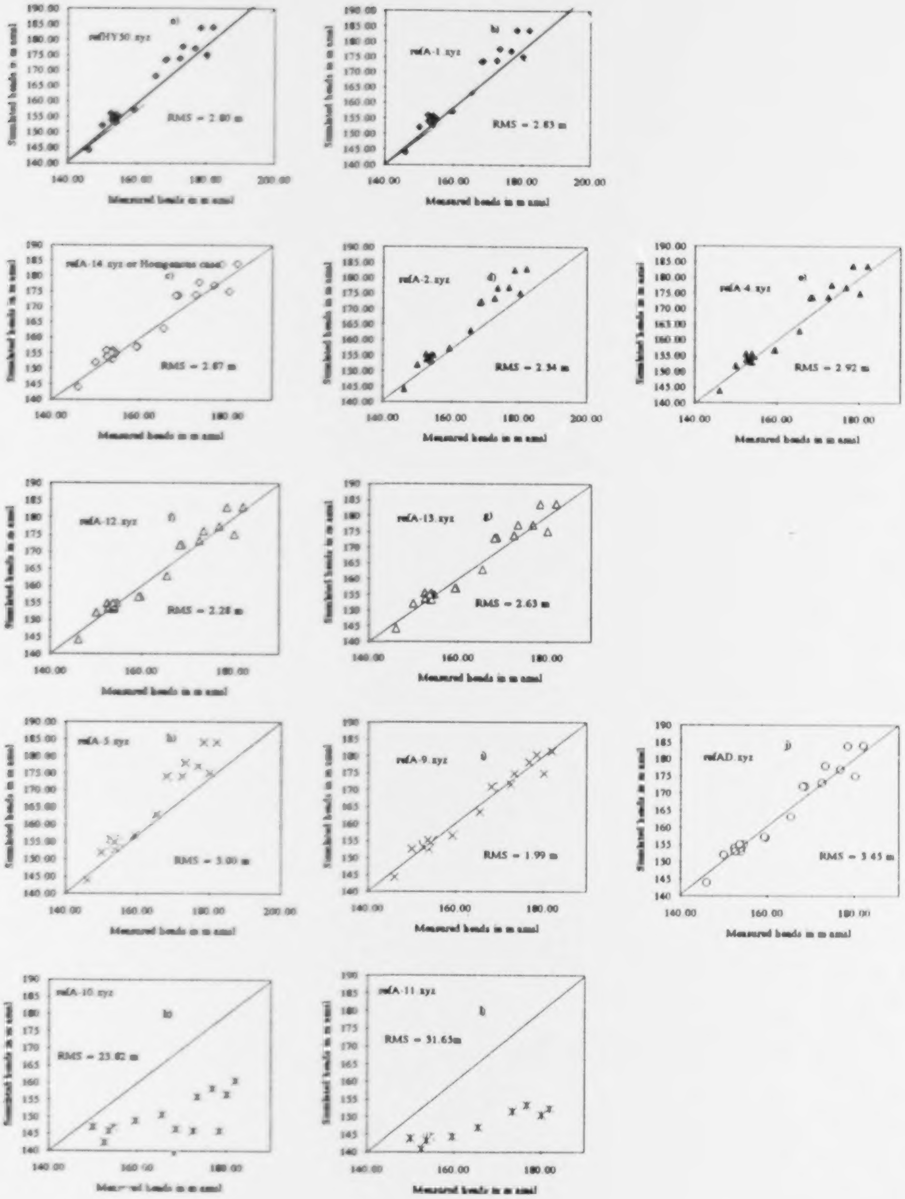


Figure 4.25 Linear regression between measured and simulated hydraulic heads in Huai Yai Hydrogeologic Province , RMS = Root mean squared error

Set#1 a) to b) Bottom boundary variation

a) For 32 Layers the bottom layer at -800 m amsl
b) For 27 Layers the bottom layer at -320 m amsl

Set# 2 c) to e) horizontal hydraulic conductivity variation
c) Homogenous case Kx=Ky=Kz=1.16E-05 m/s
d) Kx=10xKy
e) Kx= 0.1xKy

Set# 3 f) to g) Increase and decrease Kx values for twice (Kx=Ky)
f) Kx = 2Ky g) Kx=0.5 Ky

Set# 4

h) to l) Vertical hydraulic conductivity variation (Kx=Ky)
h) Vz=1E-1Kx i) Vz=1E-2
j) Vz= 1E-1 to 1E-2Kx k) Vz=1E-4
l) Vz= 1E-5Kx

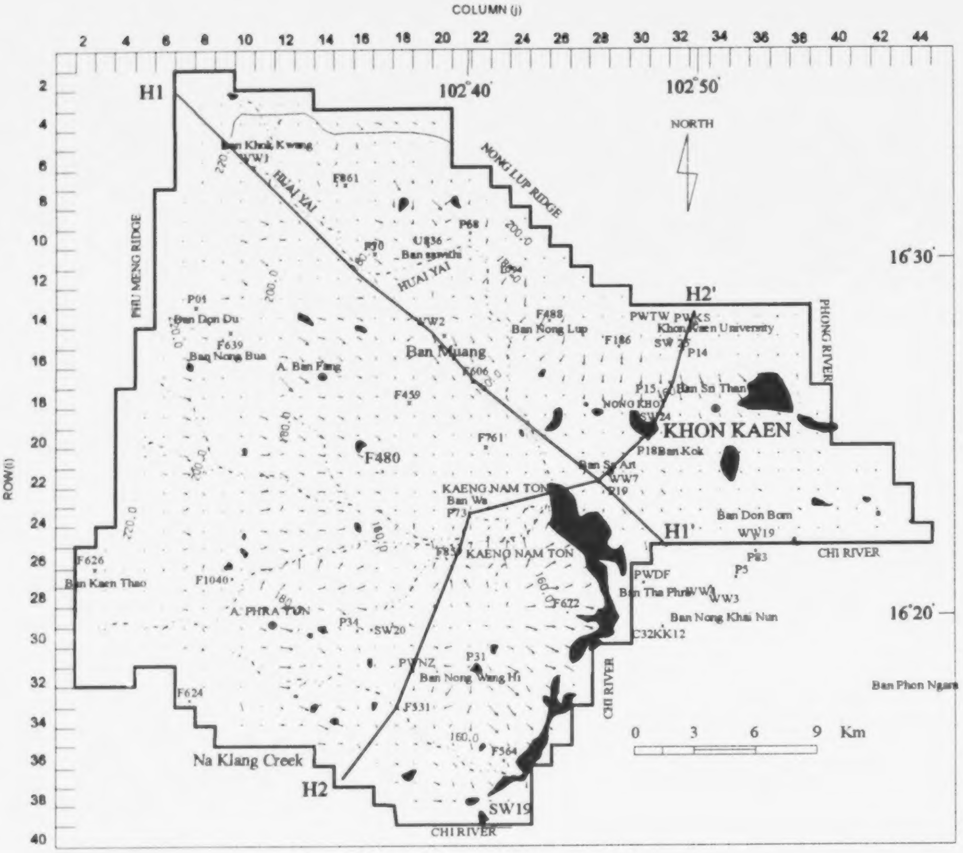

COLUMN (j)
ROW (i)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
102°40'
102°50'
16°30'
16°20'
NORTH
H1
H1'
H2
H2'
PHU MENG RIDGE
NONG LUP RIDGE
PHONG RIVER
HUAI YAI
CHI RIVER
Na Klang Creek
KHON KAEN
Ban Muang
KAENG NAM TON
Ban Khok Kwang
WW1
F861
P68
U836
Ban sawathi
P30
P01
Ban Don Du
F639
Ban Nong Bua
A. Ban Fang
WW2
F488
Ban Nong Lup
PWTW
PWKS
Khon Kaen University
SW 25
F186
P14
F606
F459
P15
Ban Sa Than
NONG KHON
SW24
P18
Ban Kok
F761
F480
Ban Sa Art
WW7
P19
Ban Wa
P73
Ban Don Bom
WW19
P83
P5
CHI RIVER
PWDF
Ban Tha Phra
WW4
WW3
Ban Nong Khai Nun
C32KK12
F622
F626
Ban Kaen Thao
F1040
A. PHRA YUN
P34
SW20
PWNZ
P31
Ban Nong Wang Hi
F624
F531
F564
SW19
Ban Phon Ngam
220.0
200.0
180.0
160.0
0 3 6 9 Km

Figure 4.26a Distribution of simulated heads and vectors of simulated horizontal groundwater flux for model layer 6 of Huai Yai Hydrogeologic Province

Stream

Lake or reservoir

H1___H1' Line of hydrogeological profile

⊕ Amphoe or district

WW1 Water wells

P20 & SW22 Piezometers and surface water

4.0×10^{-7} m/s

180 Equipotential line of simulated hydraulic heads in m amsl

Modeled boundary

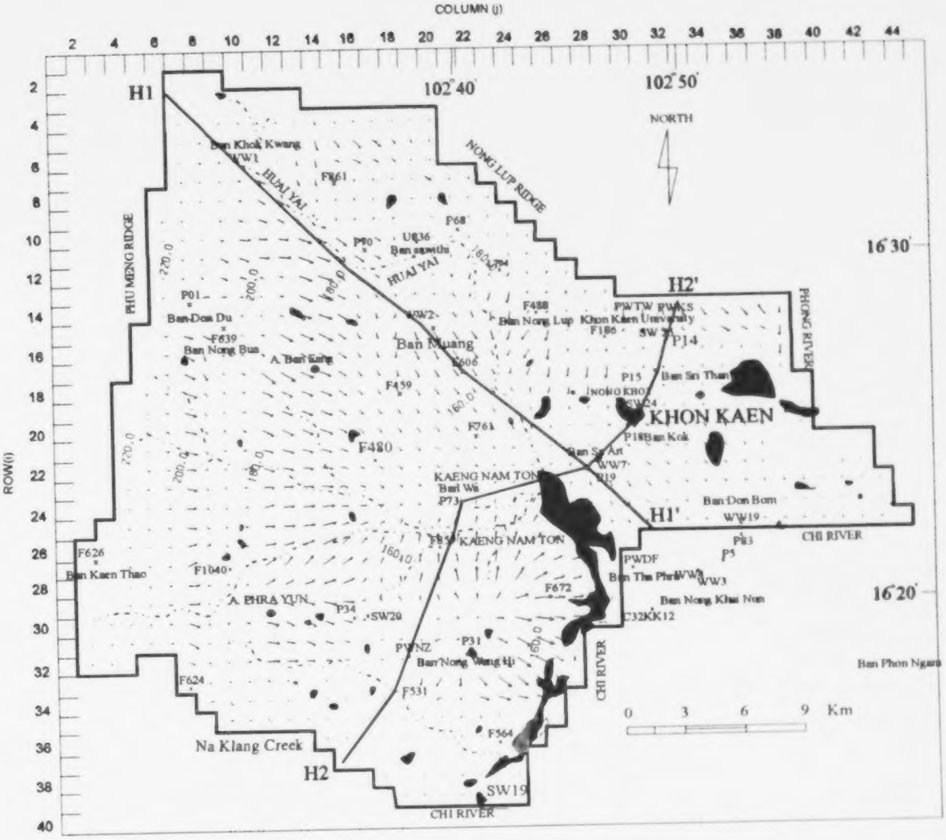
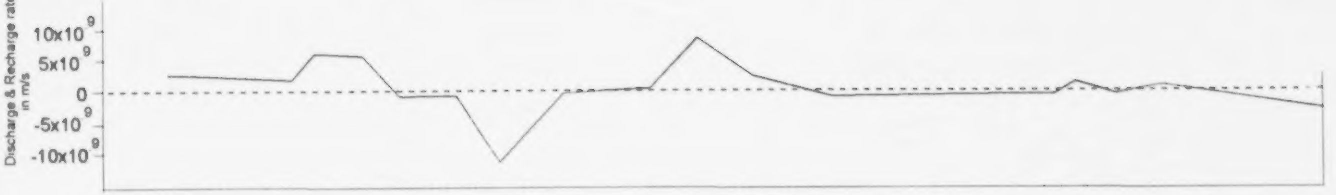
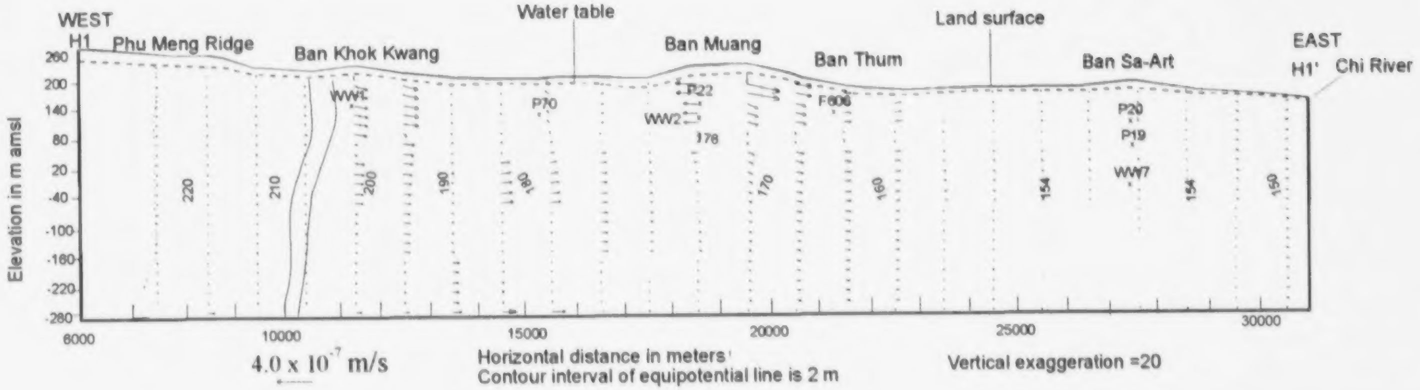

COLUMN (j)
ROW(i)
H1
H1'
H2
H2'
102°40'
102°50'
16°30'
16°20'
NORTH
PHU MENG RIDGE
NONG LUP RIDGE
HUAI YAI
PHONG RIVER
CHI RIVER
KHON KAEN
KAENG NAM TON
Ban Muang
A. PHRA YUN
Na Klang Creek
Ban Khok Kwang
WW1
Ban Nong Lup
Khon Kaen University
Ban Don Bom
Ban Tha Phra
Ban Nong Khai Nun
Ban Phon Ngam
Ban Kaen Thao
Ban Don Du
Ban Nong Bua
Ban Nong Wang Hi
P14
P15
P19
P34
P31
P01
F480
F488
F459
F761
F639
F626
F1040
F624
F531
F564
F672
SW19
SW20
WW7
WW19
WW3
PWDF
PWNZ
220.0
200.0
180.0
160.0
0 3 6 9 Km

Figure 4.26b Distribution of simulated heads and vectors of simulated horizontal groundwater flux for model layer 15 of Huai Yai Hydrogeologic Province

⋯	Stream	← 4.0 x 10^{-7}	m/s
●	Lake or reservoir	180	Equipotential line of simulated hydraulic heads in m amsl
H1____H1'	Line of hydrogeological profile		Modeled boundary
⊕	Amphoe or district		
WW1	Water wells		
P20 & SW22	Piezometers and surface water		

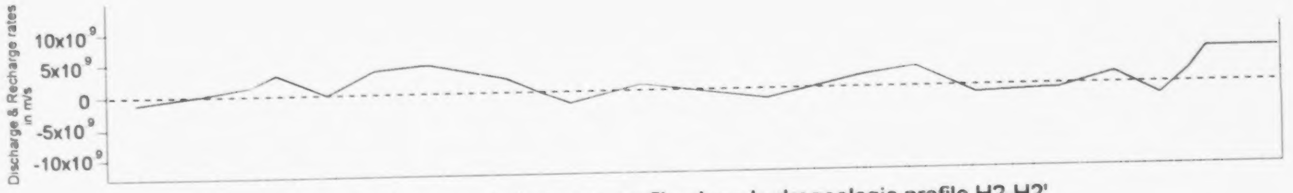


Recharge and discharge profile along hydrogeologic profile H1-H1'

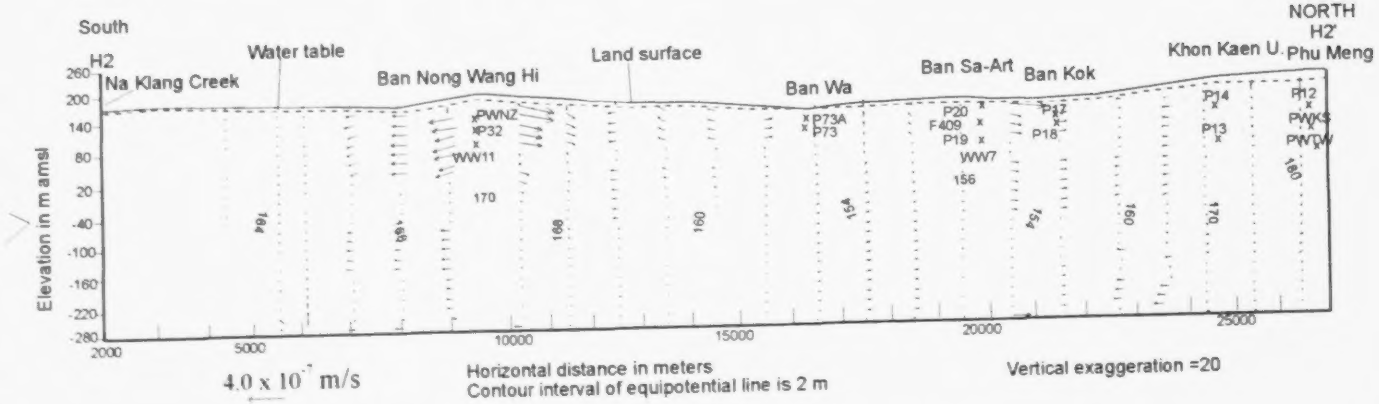


WEST
H1
Phu Meng Ridge
Ban Khok Kwang
Water table
Ban Muang
Ban Thum
Land surface
Ban Sa-Art
EAST
H1'
Chi River
Elevation in m amsl
260
200
140
80
20
-40
-100
-160
-220
-280
WW1
P70
P22
WW2
178
F606
P20
P19
WW7
220
210
200
190
180
170
160
154
154
150
6000
10000
15000
20000
25000
30000
4.0 x 10^{-7} m/s
Horizontal distance in meters
Contour interval of equipotential line is 2 m
Vertical exaggeration =20

Figure 4.27a Results of final simulated hydraulic heads and fluxes along H1-H1'
Symbols are illustrated in Figure 4.26



Recharge and discharge profile along hydrogeologic profile H2-H2'


South
H2
Na Klang Creek
Water table
Ban Nong Wang Hi
Land surface
Ban Wa
Ban Sa-Art
Ban Kok
Khon Kaen U.
NORTH
H2'
Phu Meng
PWNZ
P32
WW11
P73A
P73
P20
F409
P19
WW7
P17
P18
P14
P13
P12
PWKS
PWTW
164
168
170
166
160
154
156
154
160
170
180
Elevation in m amsl
260
200
140
80
20
-40
-100
-160
-220
-280
2000
5000
10000
15000
20000
25000
4.0 x 10⁻⁷ m/s

Horizontal distance in meters
Contour interval of equipotential line is 2 m

Vertical exaggeration =20

Figure 4.27b Results of final simulated hydraulic heads and fluxes along H2-H2'
Symbols are illustrated in Figure 4.26

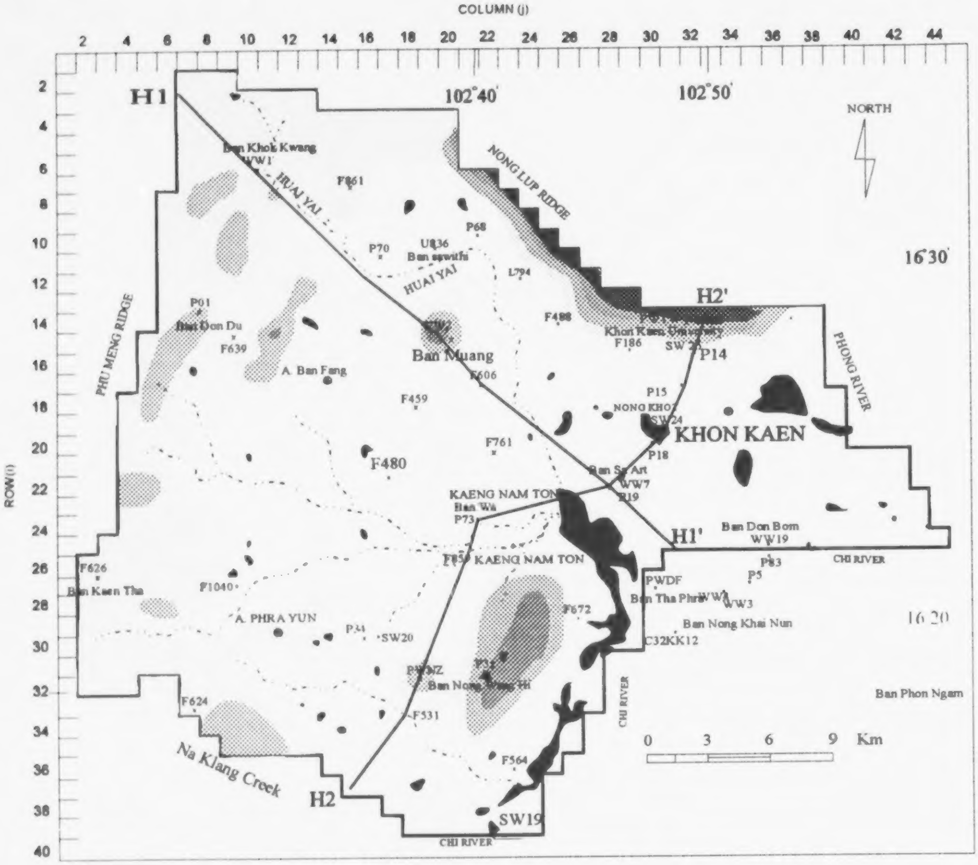

COLUMN (j)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
ROW (i)
H1
H1'
H2
H2'
102°40'
102°50'
16°30'
16°20
NORTH
NONG LUP RIDGE
PHU MENG RIDGE
PHONG RIVER
HUAI YAI
Ban Khok Kwang
WW1
F861
P70
U836
Ban sawaths
P68
L794
P01
Ban Don Du
F639
A. Ban Fang
Ban Muang
F606
F459
F488
Khon Kaen University
F186
SW22
P14
P15
NONG KHON
SW24
KHON KAEN
P18
F761
F480
Ban Sa Art
WW7
P19
KAENG NAM TON
Ban Wa
P73
Ban Don Bom
WW19
P83
P5
CHI RIVER
F626
Ban Kaen Tha
F1040
A. PHRA YUN
P34
SW20
F672
PWDF
Ban Tha Phra
WW3
Ban Nong Khai Nun
C32KK12
PWNZ
P31
Ban Nong Waeng Hi
F624
F531
Ban Phon Ngam
0
3
6
9
Km
F564
Na Klang Creek
SW19

Figure 4.28 Calculated recharge rates from model simulation of Huai Yai Hydrogeologic Province

Stream

Lake or reservoir

H1___H1' Line of hydrogeological profile

Amphoe or district

WW1 Water wells

P20 & SW22 Piezometers and surface water

Recharge rate in m/s (E-09)

>0.0 - 2.00

▨ 2.00 - 5.00

▨ 5.00 - 10.00

■ > 10.00

Model boundary

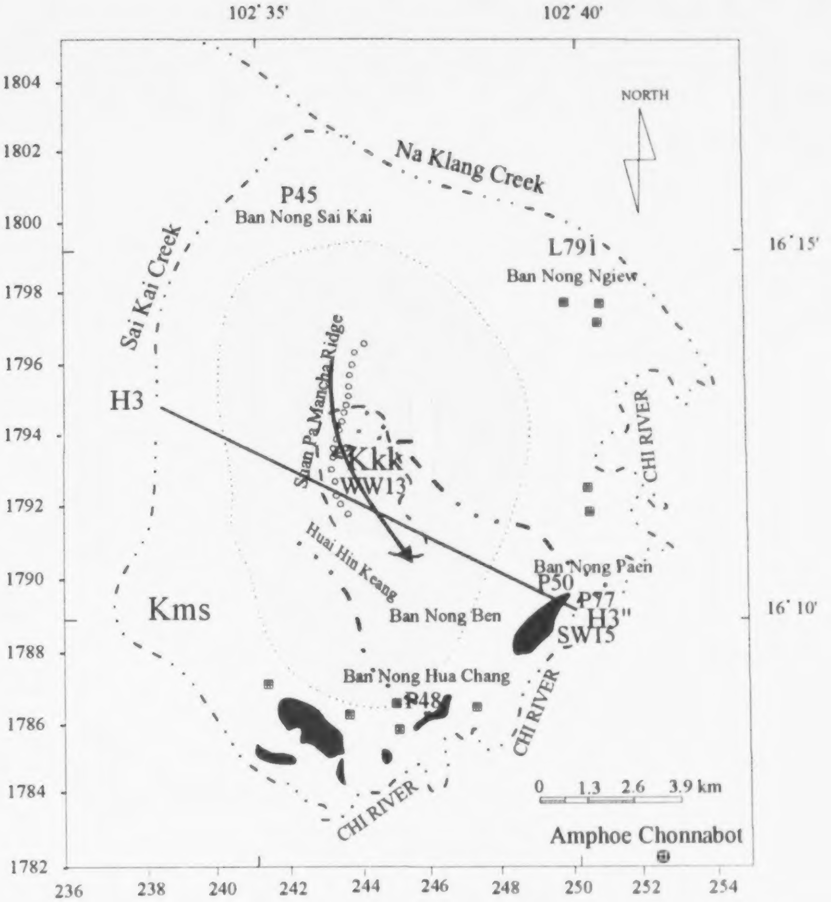
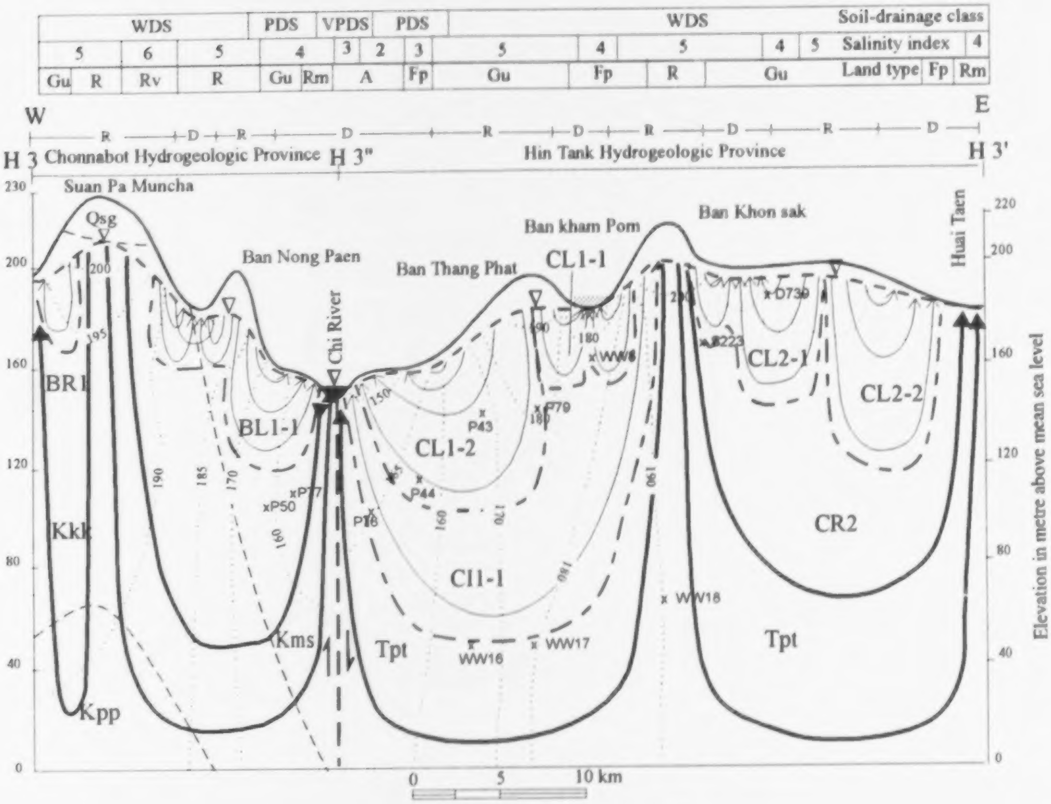

102° 35'
102° 40'
1804
1802
1800
1798
1796
1794
1792
1790
1788
1786
1784
1782
236
238
240
242
244
246
248
250
252
254
16° 15'
16° 10'
NORTH
Na Klang Creek
Sai Kai Creek
P45
Ban Nong Sai Kai
L791
Ban Nong Ngiew
H3
Shan Pa Mancha Ridge
Kkk
WW13
Huai Hin Keang
Kms
Ban Nong Ben
Ban Nong Paen
P50
P77
H3"
SW15
CHI RIVER
Ban Nong Hua Chang
P48
CHI RIVER
CHI RIVER
0 1.3 2.6 3.9 km
Amphoe Chonnabot

Figure 5.1 Distribution of recharge and discharge area and major aquifers in Chonnabot Hydrogeologic Province

⋯	Stream	■	Area of saline soil
●	Lake or reservoir	– – –	Hydrogeologic boundary
H3 —— H3'''	Line of hydrogeologic profile	Kkk	Khok Kruat unit
WW13	Water wells	Kms	Mahasarakham unit
P50	Piezometers	☐	Recharge area
○○○	Surface water and groundwater divide	☐	Discharge area
		⟶	Anticline


WDS
PDS
VPDS
PDS
WDS
Soil-drainage class
5 6 5 4 3 2 3 5 4 5 4 5
Salinity index
4
Gu R Rv R Gu Rm A Fp Gu Fp R Gu
Land type
Fp Rm
W
E
R D R D R D R D R D
H 3
Chonnabot Hydrogeologic Province
H 3"
Hin Tank Hydrogeologic Province
H 3'
Suan Pa Muncha
Qsg
Ban Nong Paen
Chi River
Ban Thang Phat
Ban kham Pom
CL1-1
Ban Khon sak
Huai Taen
BR1
BL1-1
CL1-2
CL2-1
CL2-2
CI1-1
CR2
Kkk
Kms
Kpp
Tpt
Tpt
P43
P79
P44
P50
P77
P18
WW8
WW16
WW17
WW18
D739
S223
200
195
190
185
170
160
150
160
170
180
180
190
230
200
160
120
80
40
0
220
200
160
120
80
40
0
0 5 10 km
Elevation in metre above mean sea level

Vertical exaggeration = 125

Figure 5.2 Hydrogeologic profile H3- H3'

160	Line of equal hydraulic head (5 m contour interval)	▨	Area of observed flowing wells
- - ∇ -	Water table	R	Recharge area (downward flow)
	Flow Systems	D	Discharge area (upward flow)
	Local (CL1-1)		Concealed fault
	Intermediate (CI1-1)	- - - - - -	Geologic boundary
	Regional (CR1)	Qsg	Quaternary sand and gravel
— — - -	Flow system boundary	Tpt	Tertiary Phu Tok
x	Bottom of wells and piezometers	Kms	Cretaceous Mahasarakam Formation
	Ground surface	Kkk	Cretaceous Khok Kruat Formation
		Kpp	Cretaceous Phu Phan Formation

Geomorphic parameters are defined in Figures 4.13 to 4.16

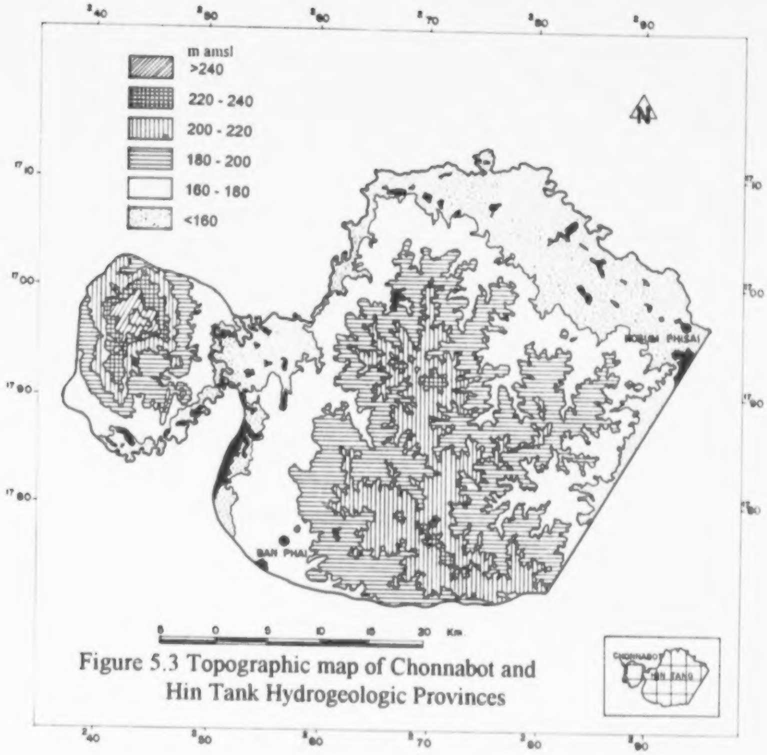

m amsl
>240
220 - 240
200 - 220
180 - 200
160 - 180
<160
N
KOSUM PHISAI
BAN PHAI
5 0 5 10 15 20 Km
CHONNABOT
HIN TANG
240
250
260
270
280
290
1710
1700
1790
1780

Figure 5.3 Topographic map of Chonnabot and Hin Tank Hydrogeologic Provinces

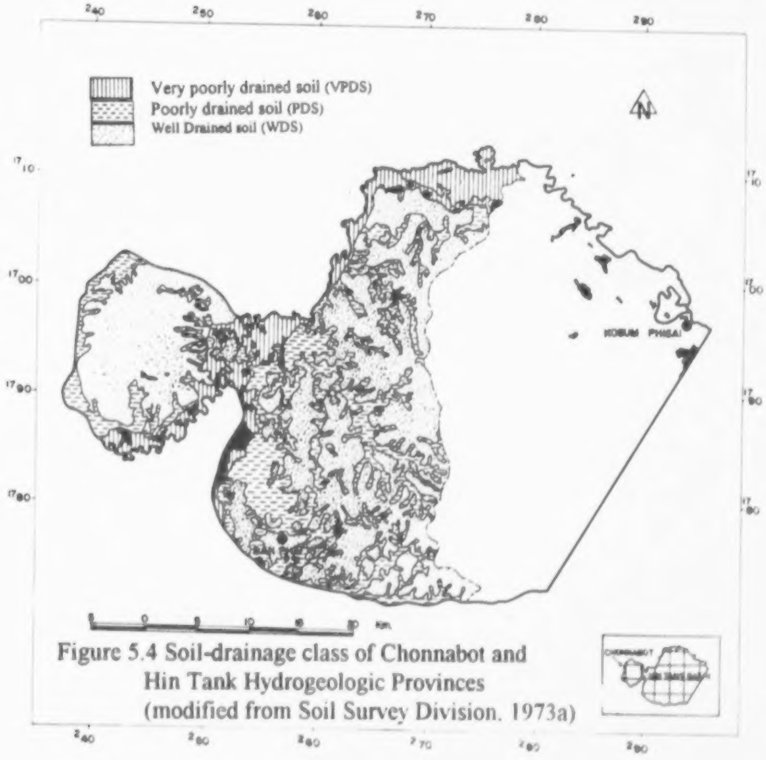

Very poorly drained soil (VPDS)
Poorly drained soil (PDS)
Well Drained soil (WDS)
N
KOSUM PHISAI
BAN PHAI
5 0 5 10 15 20 Km
CHONNABOT
HIN TANG
240
250
260
270
280
290
1710
1700
1790
1780

Figure 5.4 Soil-drainage class of Chonnabot and Hin Tank Hydrogeologic Provinces (modified from Soil Survey Division. 1973a)

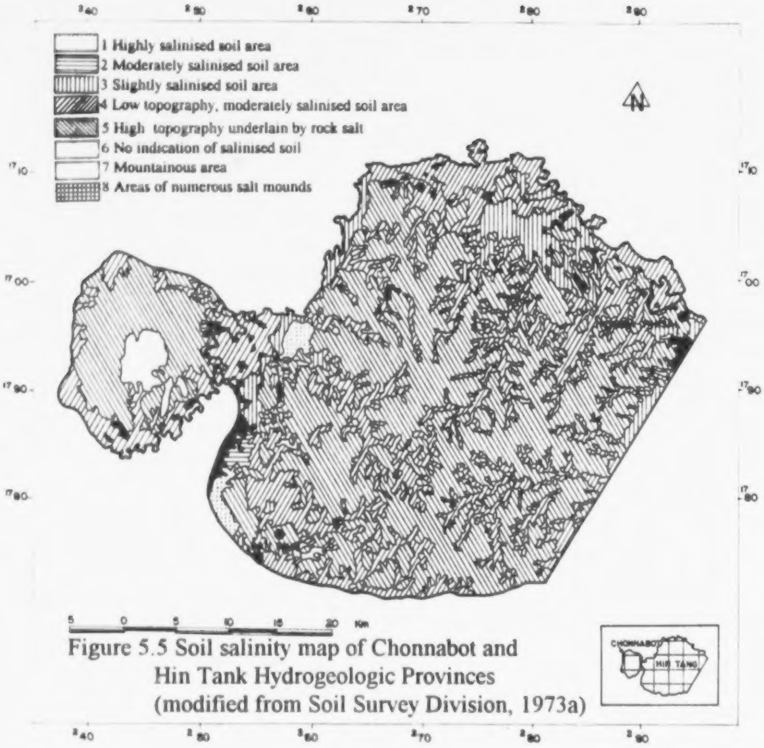

1 Highly salinised soil area
2 Moderately salinised soil area
3 Slightly salinised soil area
4 Low topography, moderately salinised soil area
5 High topography underlain by rock salt
6 No indication of salinised soil
7 Mountainous area
8 Areas of numerous salt mounds
N
5 0 5 10 15 20 Km
CHONNABOT
HIN TANG

Figure 5.5 Soil salinity map of Chonnabot and Hin Tank Hydrogeologic Provinces (modified from Soil Survey Division, 1973a)

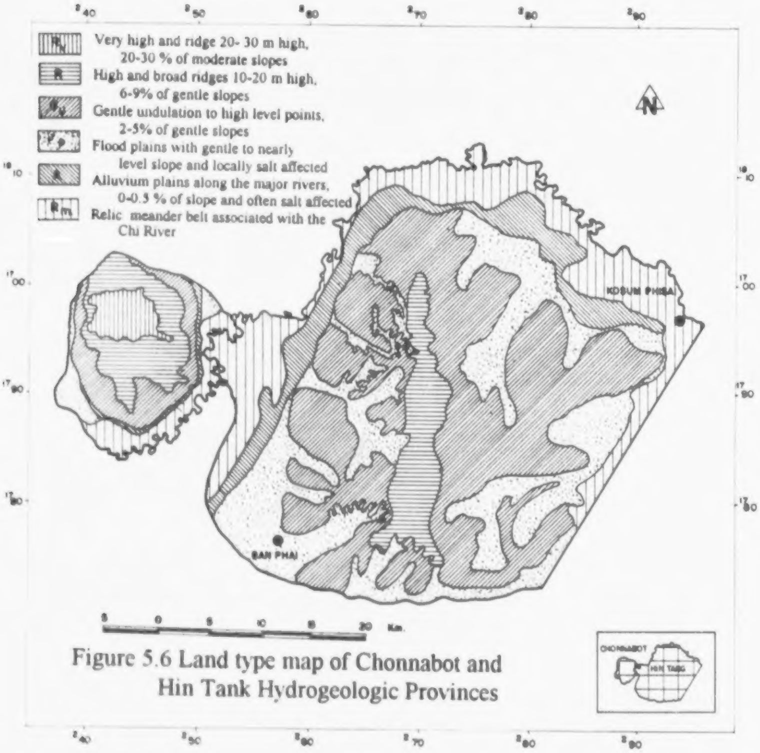

Very high and ridge 20- 30 m high, 20-30 % of moderate slopes
High and broad ridges 10-20 m high, 6-9% of gentle slopes
Gentle undulation to high level points, 2-5% of gentle slopes
Flood plains with gentle to nearly level slope and locally salt affected
Alluvium plains along the major rivers, 0-0.5 % of slope and often salt affected
Relic meander belt associated with the Chi River
N
KOSUM PHISAI
BAN PHAI
5 0 5 10 15 20 Km
CHONNABOT
HIN TANG

Figure 5.6 Land type map of Chonnabot and Hin Tank Hydrogeologic Provinces

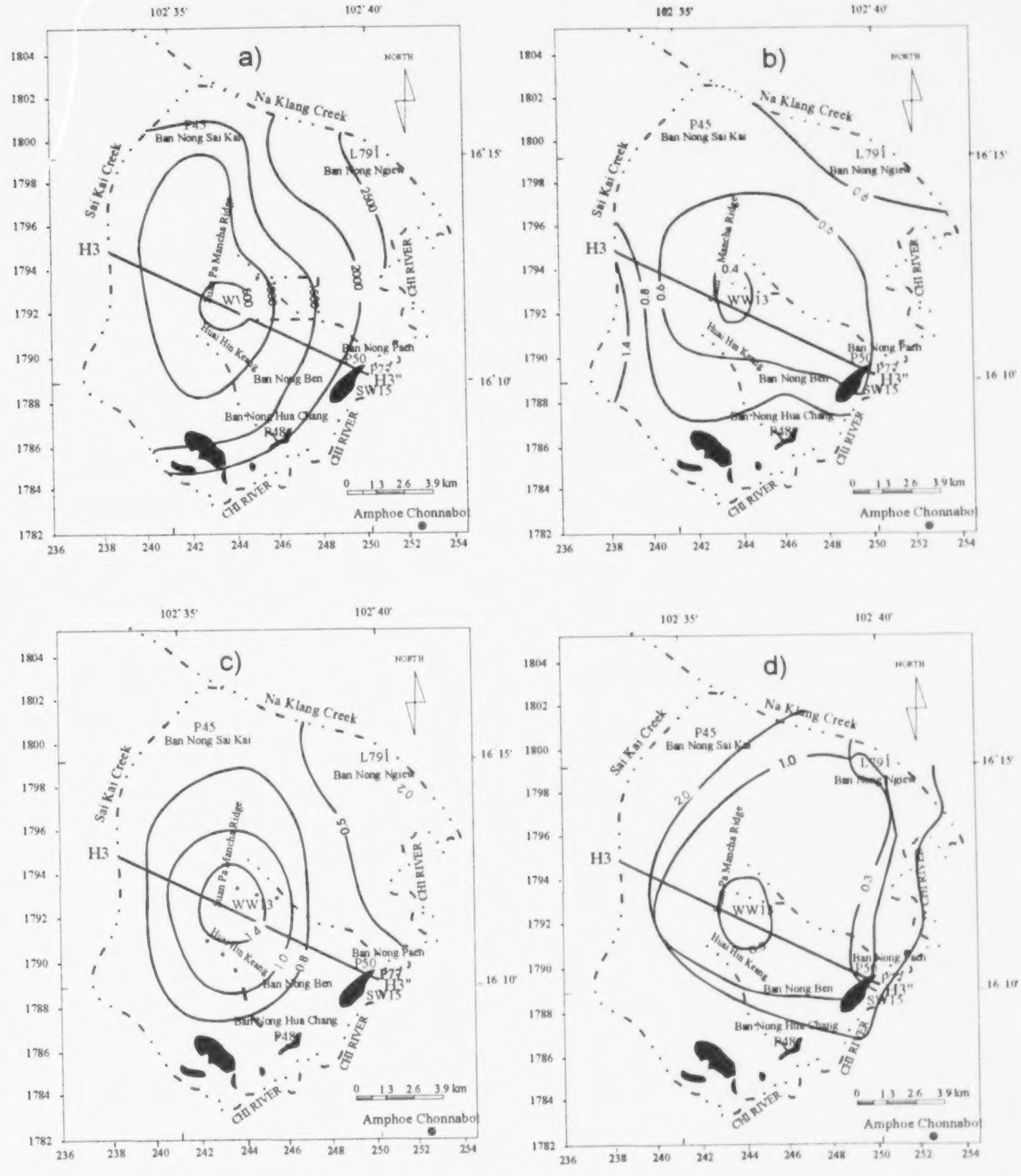

a)
b)
c)
d)
102° 35'
102° 40'
16° 15'
16° 10'
NORTH
Na Klang Creek
Sai Kai Creek
P45
Ban Nong Sai Kai
L79
Ban Nong Ngiew
Pa Mancha Ridge
WW13
Huai Hin Keang
Ban Nong Ben
Ban Nong Pach
P50
P77
H3
H3"
SW15
Ban Nong Hua Chang
P48
CHI RIVER
Amphoe Chonnabot
0 1.3 2.6 3.9 km
2500
2000
1500
1000
500
0.8
0.6
0.4
1.4
0.5
1.0
2.0
0.3
1804
1802
1800
1798
1796
1794
1792
1790
1788
1786
1784
1782
236
238
240
242
244
246
248
250
252
254

Figure 5.7 Distribution of TDS and ionic ratios in Chonnabot Hydrogeologic Province

a) TDS contents (mg/l)
b) magnesium to calcium ratio
c) calcium to sodium ratio
d) sulphate to chloride ratio

Stream
Lake or reservoir
H3 H3" Line of hydrogeologic profile
WW13 Water wells
P50 Piezometers

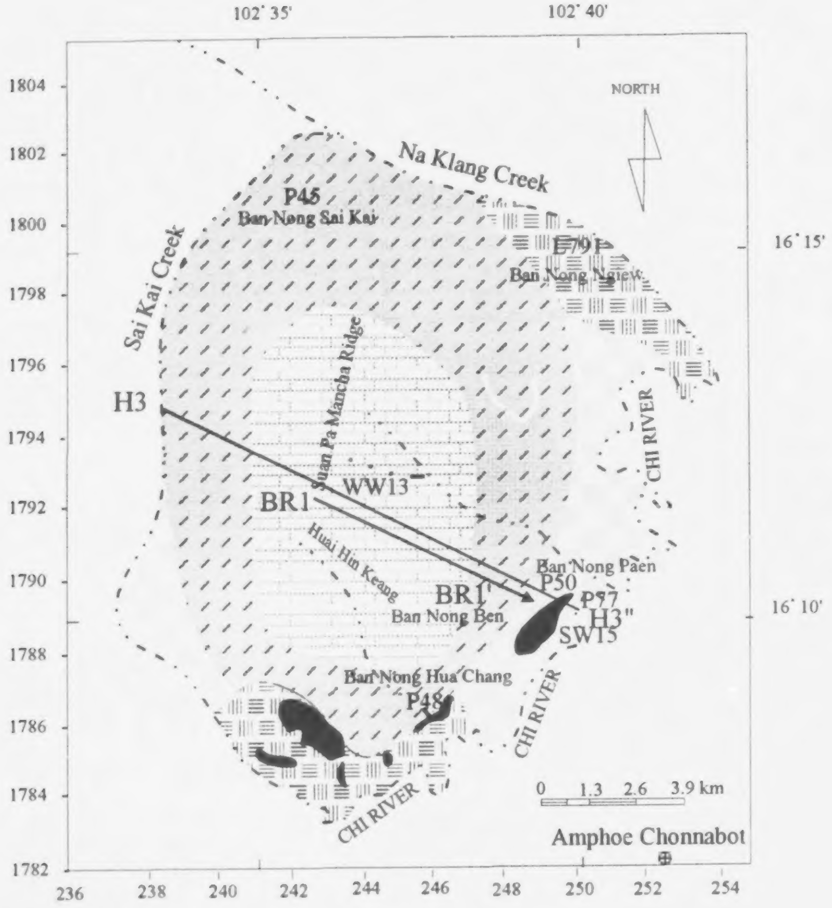

102° 35'
102° 40'
NORTH
1804
1802
1800
1798
1796
1794
1792
1790
1788
1786
1784
1782
16° 15'
16° 10'
236
238
240
242
244
246
248
250
252
254
Na Klang Creek
Sai Kai Creek
P45
Ban Nong Sai Kai
E79
Ban Nong Ngiew
Suan Pa Mancha Ridge
H3
WW13
BR1
Huai Hin Keang
CHI RIVER
Ban Nong Paen
P50
BR1'
P77
H3"
Ban Nong Ben
SW15
Ban Nong Hua Chang
P48
CHI RIVER
CHI RIVER
0 1.3 2.6 3.9 km
Amphoe Chonnabot

Figure 5.8 Distribution of hydrochemical facies
Chonnabot Hydrogeologic Province

Stream

Lake or reservoir

H3 H3" Line of hydrogeologic profile

WW13 Water wells

P50 Piezometers

BR1 BR1' Flow path

Hydrochemical facies	Average TDS in mg/l
Ca-HCO3	400
▨ Ca-Na-HCO3	500
▤ Na-SO4-Cl	5200
☐ Na-Cl	2100 - 20,000

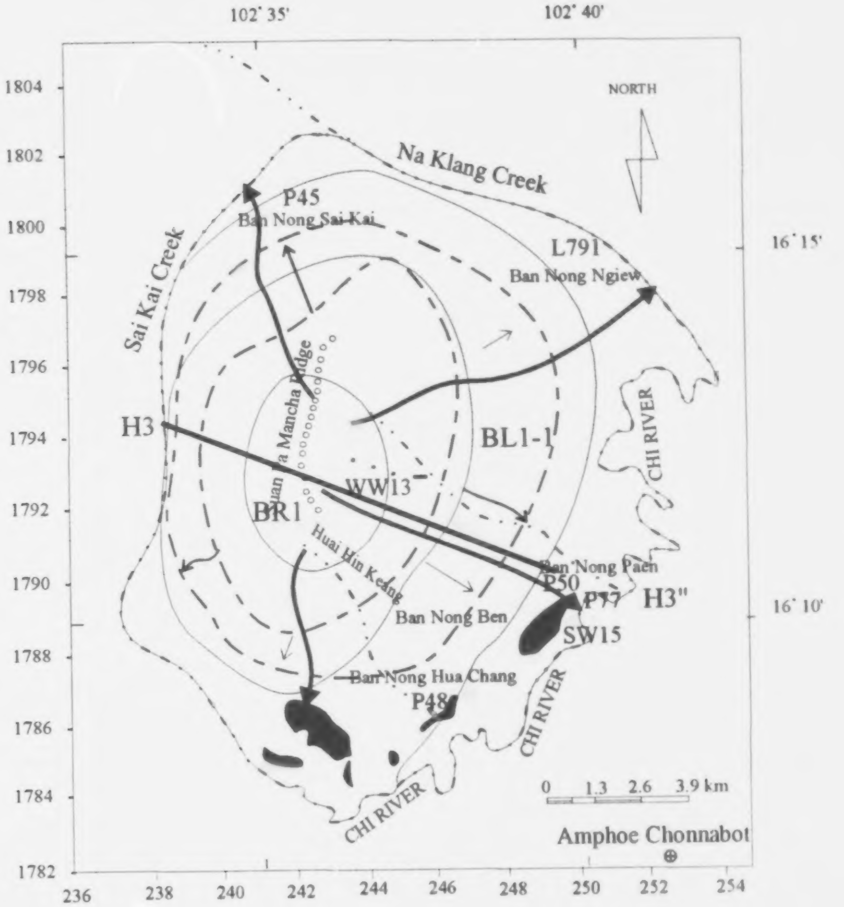

102° 35'
102° 40'
1804
1802
1800
1798
1796
1794
1792
1790
1788
1786
1784
1782
236
238
240
242
244
246
248
250
252
254
16° 15'
16° 10'
NORTH
Na Klang Creek
Sai Kai Creek
P45
Ban Nong Sai Kai
L791
Ban Nong Ngiew
Huan Na Mancha Ridge
H3
BL1-1
WW13
BR1
Huai Hin Keang
Ban Nong Paen
P50
P77
H3"
Ban Nong Ben
SW15
Ban Nong Hua Chang
P48
CHI RIVER
CHI RIVER
CHI RIVER
0 1.3 2.6 3.9 km
Amphoe Chonnabot

Figure 5.9 Distribution of hydraulic heads, groundwater flow paths and flow systems in Chonnabot Hydrogeologic Province

Stream

Lake or reservoir

H3 H3" Line of hydrogeologic profile

WW13 x Water wells

P50 x Piezometers

180 Equipotential line (10 m

Flow path and direction

Local

Regional

Flow system boundary

Fow systems

Regional

BR1 Huai Hin Keang

Local

BL1-1 Ban Nong Paen

Surface water and groundwater divide

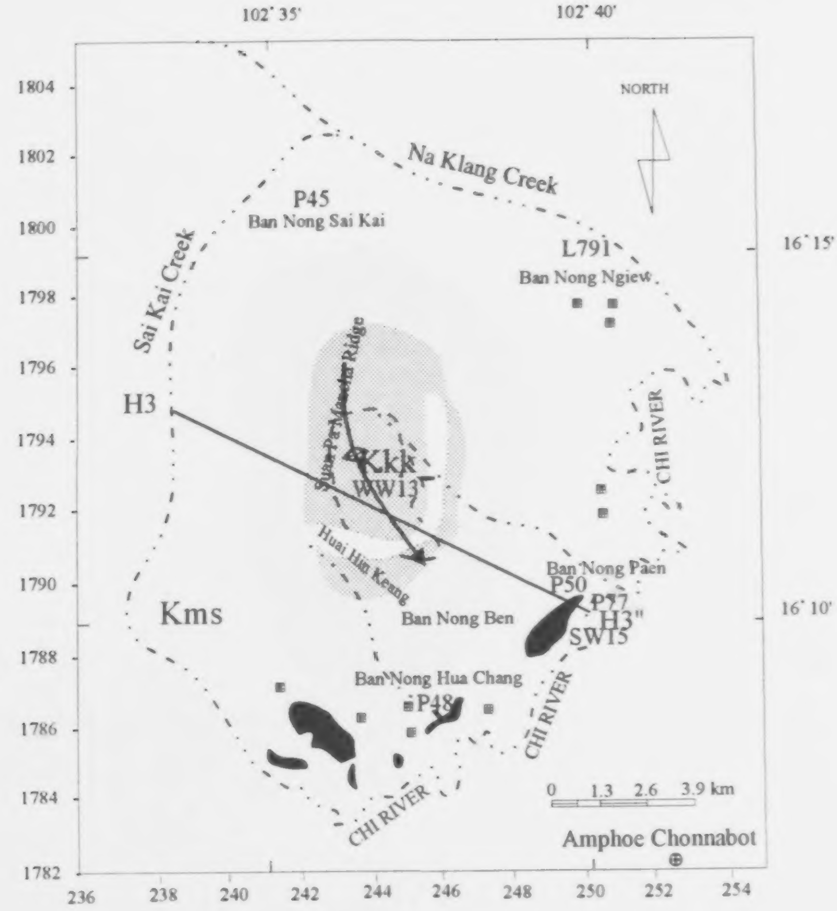

102° 35'
102° 40'
1804
1802
1800
1798
1796
1794
1792
1790
1788
1786
1784
1782
236
238
240
242
244
246
248
250
252
254
16° 15'
16° 10'
NORTH
Na Klang Creek
P45
Ban Nong Sai Kai
Sai Kai Creek
L791
Ban Nong Ngiew
H3
Suan Pa Maeoha Ridge
Kkk
WW13
CHI RIVER
Huai Hin Keang
Ban Nong Paen
P50
P77
H3"
SW15
Kms
Ban Nong Ben
Ban Nong Hua Chang
P48
CHI RIVER
CHI RIVER
0 1.3 2.6 3.9 km
Amphoe Chonnabot

Figure 5.10 Distribution of calculated recharge rates estimated by water level fluctuation in Chonnabot Hydrogeologic Province

Stream		Recharge rate in m/s (E-09)
Lake or reservoir		>0 - 2.00
H3"——H3'	Line of hydrogeologic profile	▨ 2.00 - 5.00
WW13	Water wells	▨ 5.00 - 10.00
P50	Piezometers	

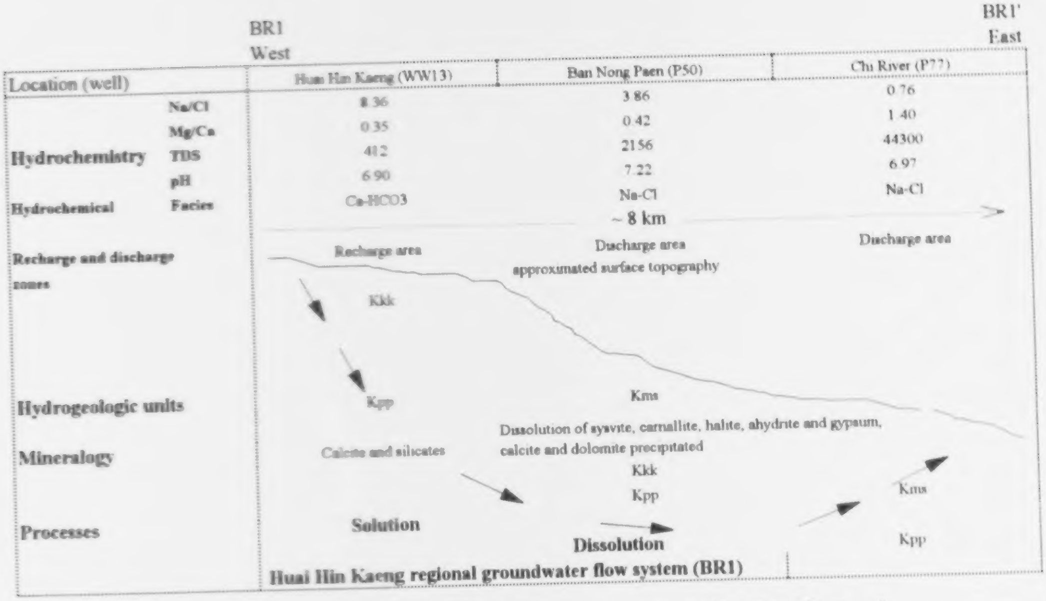

BR1
West
BR1'
East
Location (well)
Huai Hin Kaeng (WW13)
Ban Nong Paen (P50)
Chi River (P77)
Hydrochemistry
Na/Cl
Mg/Ca
TDS
pH
Hydrochemical Facies
8.36
0.35
412
6.90
Ca-HCO3
3.86
0.42
2156
7.22
Na-Cl
0.76
1.40
44300
6.97
Na-Cl
~ 8 km
Recharge and discharge zones
Recharge area
Discharge area
approximated surface topography
Discharge area
Kkk
Hydrogeologic units
Kpp
Kms
Mineralogy
Calcite and silicates
Dissolution of sylvite, carnallite, halite, ahydrite and gypsum, calcite and dolomite precipitated
Kkk
Kpp
Kms
Processes
Solution
Dissolution
Kpp
Huai Hin Kaeng regional groundwater flow system (BR1)

Figure 5.11 Schematic diagram showing hydrochemical processes along BR1-BR1' flow path in Chonnabot Hydrogeologic Province

→ Flow line Qsg = Sand and gravel unit
Kms =Mahasarakham unit
Kkk =Khok Kruat unit
Kpp =Phu Phan unit

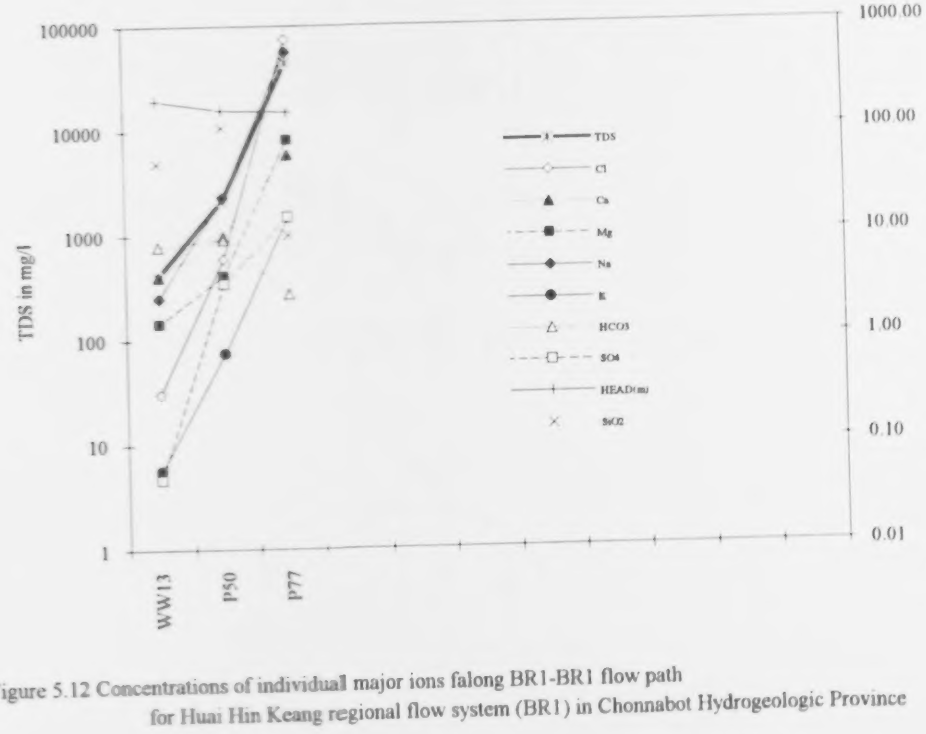


Figure 5.12 Concentrations of individual major ions falong BR1-BR1 flow path for Huai Hin Keang regional flow system (BR1) in Chonnabot Hydrogeologic Province

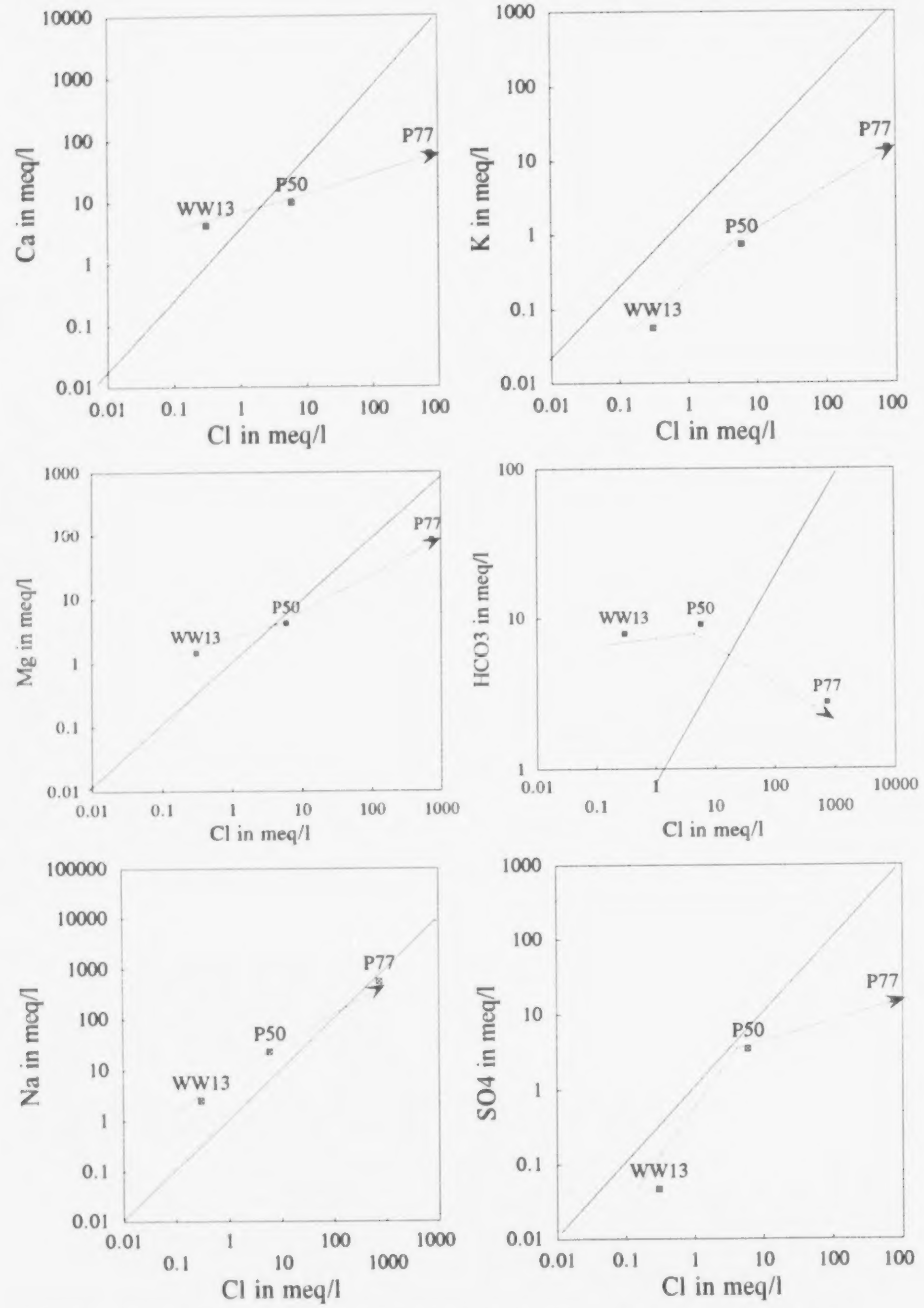


Figure 5.13 Concentrations of individual major ions related to chloride ion for BR1-BR1' flow path in Chonnabot Hydrogeologic Province

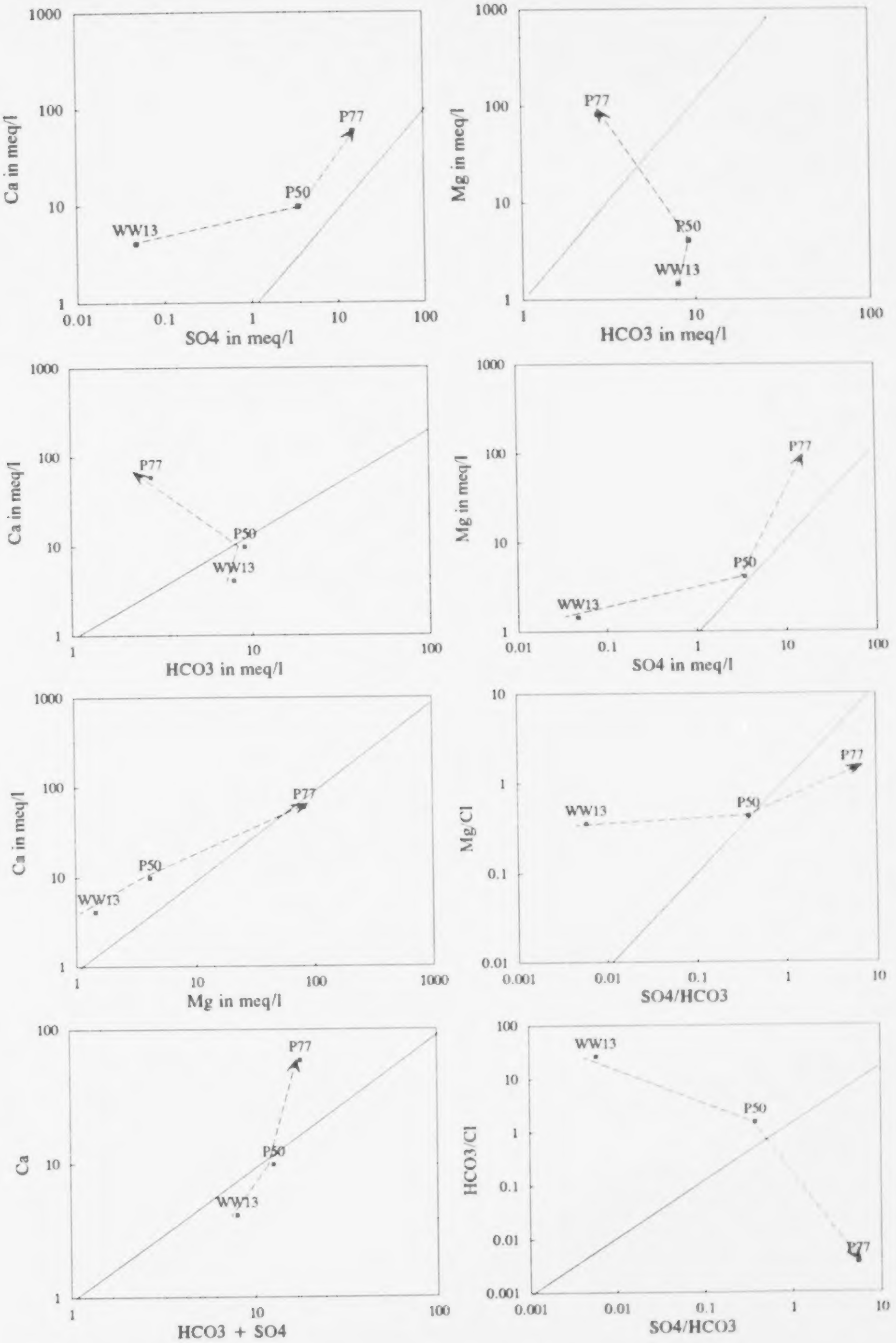


Figure 5.14 Relationship of ionic parameters along BR1-BR1' flow path in Chonnabot Hydrogeologic Province (Huai Hin Kaeng systems, BR1)

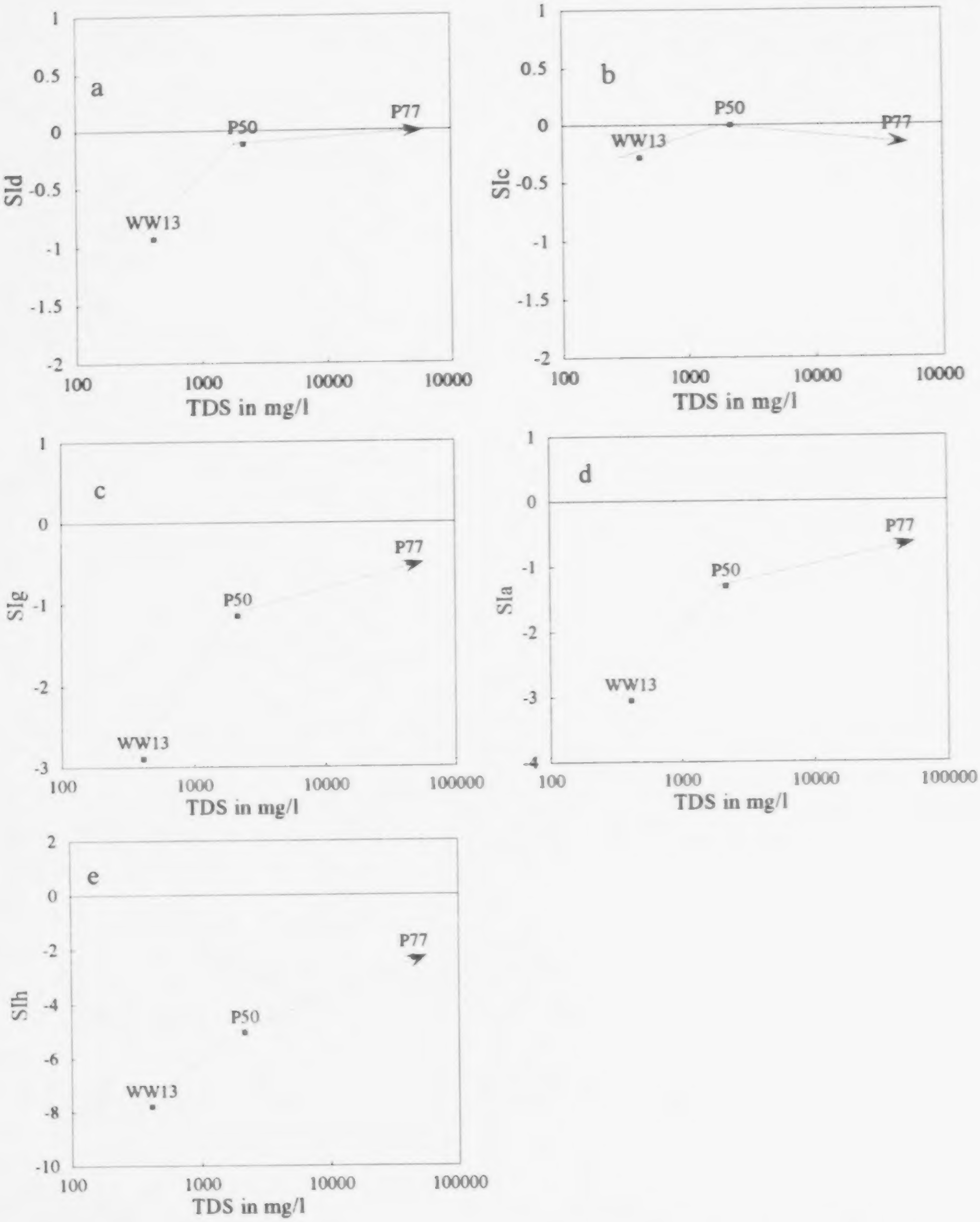


Figure 5.15 Saturation indices with respect to a) dolomite, b) calcite, c) gypsum, d) anhydrite and e) halite, as a function of TDS contents in groundwater along BR1-BR1' flow path in Chonnabot Hydrogeologic Province

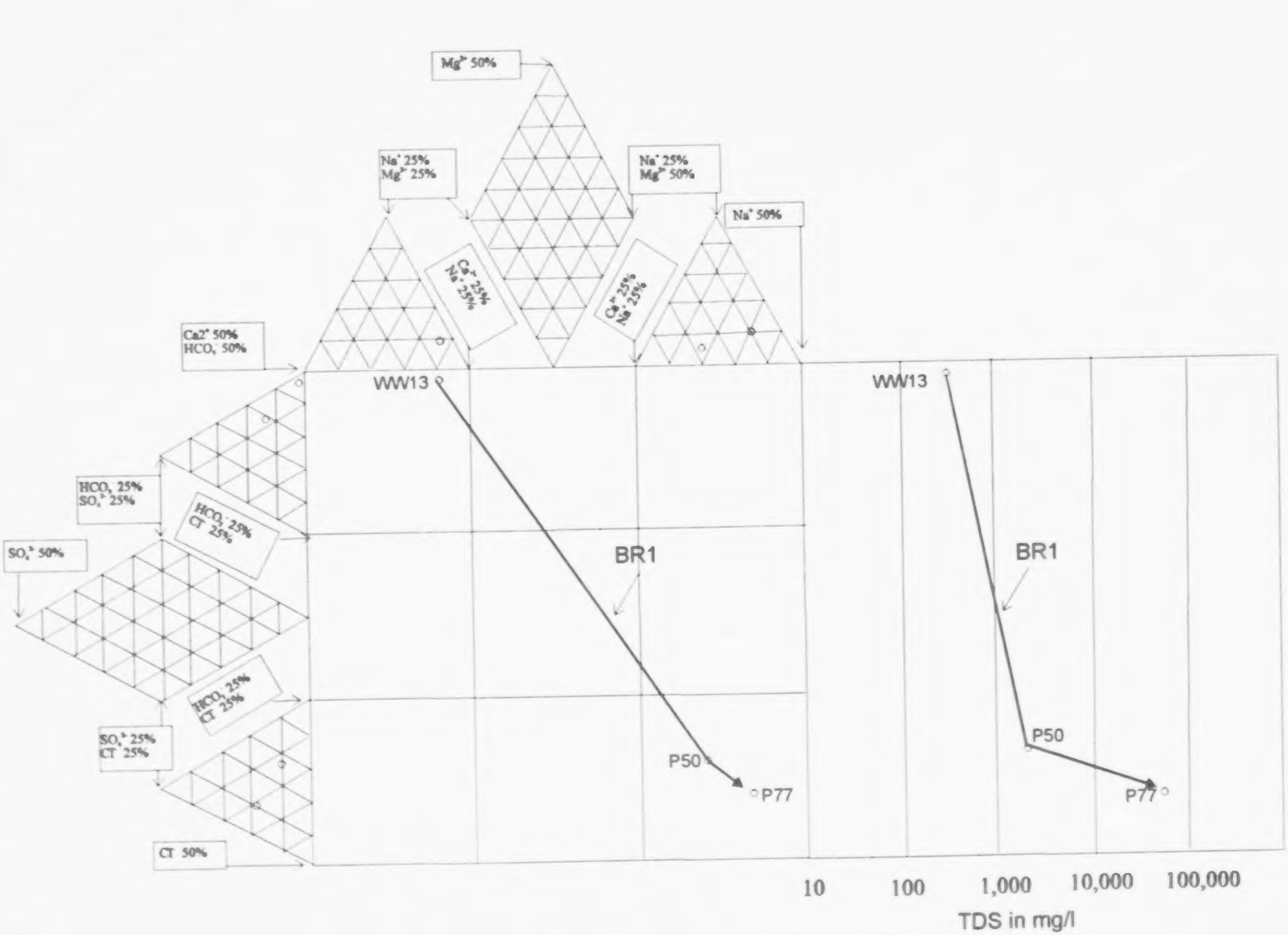


Figure 5.16 Expanded Durov diagram of selected groundwater samples along the flow path BR1 in Chonnabot Hydrogeologic Province

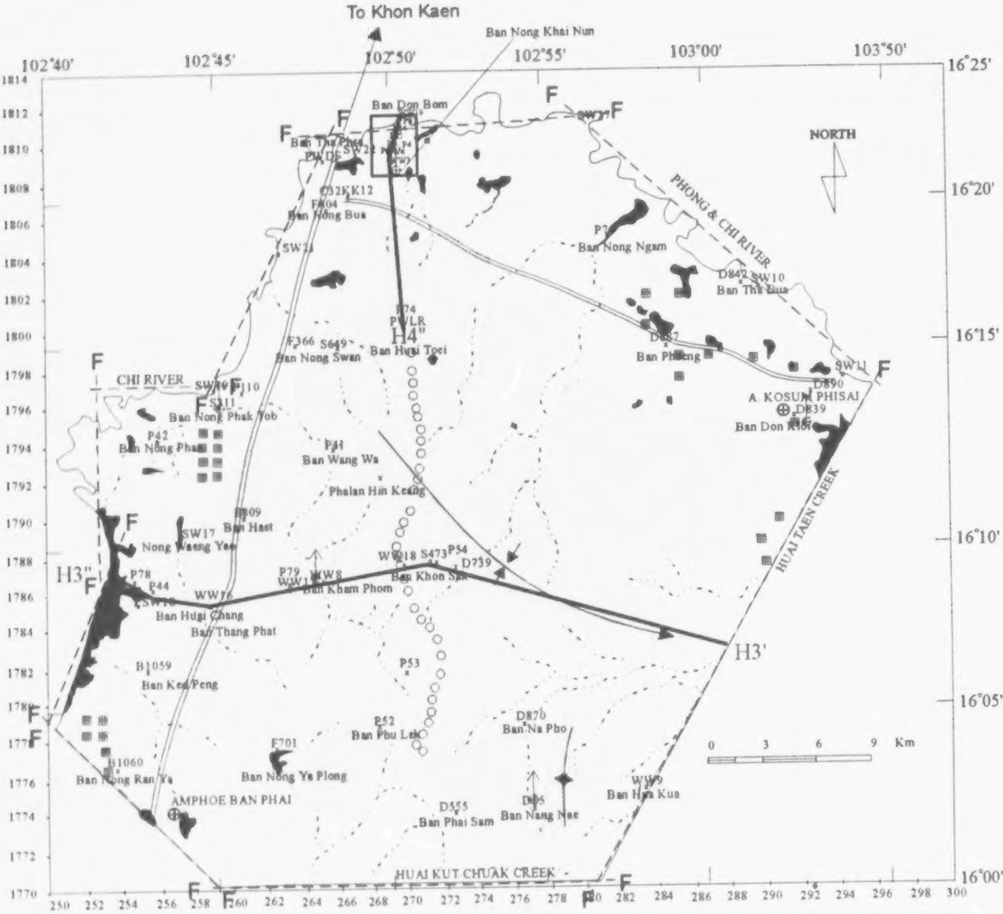

To Khon Kaen
Ban Nong Khai Nun
102°40'
102°45'
102°50'
102°55'
103°00'
103°50'
16°25'
16°20'
16°15'
16°10'
16°05'
16°00'
NORTH
PHONG & CHI RIVER
HUAI TAEN CREEK
HUAI KUT CHUAK CREEK
CHI RIVER
Ban Don Bom
Ban Tha Phra
Ban Nong Bua
Ban Nong Ngam
Ban Tha Bua
Ban Phaeng
A. KOSUM PHISAI
Ban Don Khoi
Ban Nong Swan
Ban Huai Toei
Ban Nong Phak Tob
Ban Nong Phai
Ban Wang Wa
Phalan Hin Keang
Ban Hast
Nong Waeng Yae
Ban Khon San
Ban Kham Phom
Ban Huai Chang
Ban Thang Phat
Ban Kea Peng
Ban Phu Lek
Ban Na Pho
Ban Nong Ya Plong
Ban Nong Ran Ya
AMPHOE BAN PHAI
Ban Phai Sam
Ban Nang Nae
Ban Hua Kua
H4"
H3"
H3'
F
0 3 6 9 Km
1814 1812 1810 1808 1806 1804 1802 1800 1798 1796 1794 1792 1790 1788 1786 1784 1782 1780 1778 1776 1774 1772 1770
250 252 254 256 258 260 262 264 266 268 270 272 274 276 278 280 282 284 286 288 290 292 294 296 298 300

Figure 6.1 Distribution of recharge and discharge areas and surface manifestations in Hin Tank Hydrogeologic Province

Stream

Lake or reservoir

H3"——H3' Line of hydrogeological profile

⊕ Amphoe or district

Road and highway

WW4 Water wells

P1 & SW22 Piezometers and surface water

F- - - - - F Fault

Syncline, plunge

▪ Area of saline soil

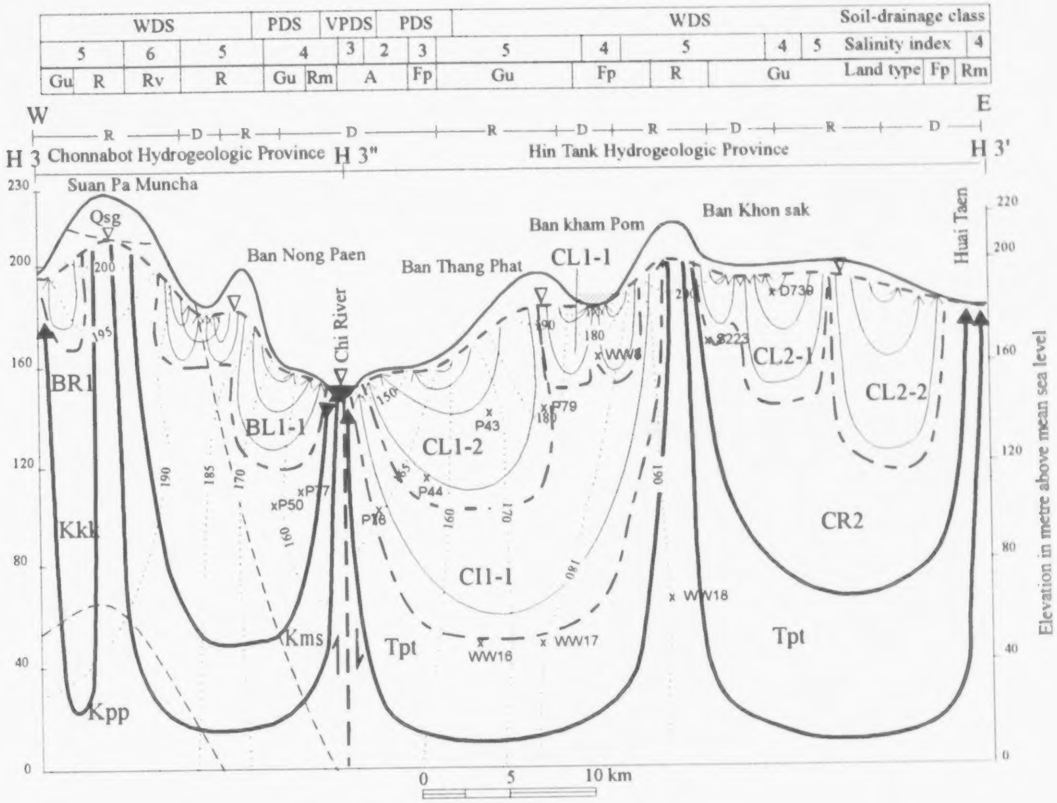
Flowing well

○○○○○ Surface water and groundwater divide

Recharge area

Discharge area

Hydrogeologic province boundary


WDS
PDS
VPDS
PDS
WDS
Soil-drainage class
5
6
5
4
3
2
3
5
4
5
4
5
Salinity index
4
Gu
R
Rv
R
Gu
Rm
A
Fp
Gu
Fp
R
Gu
Land type
Fp
Rm
W
E
R
D
R
D
R
D
R
D
R
D
H 3
Chonnabot Hydrogeologic Province
H 3"
Hin Tank Hydrogeologic Province
H 3'
Suan Pa Muncha
Qsg
Ban Nong Paen
Chi River
Ban Thang Phat
Ban kham Pom
CL1-1
Ban Khon sak
Huai Taen
BR1
BL1-1
CL1-2
CL2-1
CL2-2
Kkk
CI1-1
CR2
Kms
Tpt
Tpt
Kpp
P43
P79
P44
P50
P77
P18
WW8
WW16
WW17
WW18
D739
S223
200
195
190
185
170
160
150
165
160
170
180
180
190
190
200
230
200
160
120
80
40
0
220
200
160
120
80
40
0
Elevation in metre above mean sea level
0
5
10 km

Vertical exaggeration = 125

Figure 6.2 Hydrogeologic profile H3- H3'

160	Line of equal hydraulic head (5 m contour interval)	▨	Area of observed flowing wells
– –∇– –	Water table	R	Recharge area (downward flow)
	Flow Systems	D	Discharge area (upward flow)
	Local (CL1-1)	⇄	Concealed fault
	Intermediate (CI1-1)	- - - - -	Geologic boundary
	Regional (CR1)	Qsg	Quaternary sand and gravel
– — – –	Flow system boundary	Tpt	Tertiary Phu Tok
x	Bottom of wells and piezometers	Kms	Cretaceous Mahasarakam Formation
	Ground surface	Kkk	Cretaceous Khok Kruat Formation
		Kpp	Cretaceous Phu Phan Formation

Geomorphic parameters are defined in Figures 4.13 to 4.16

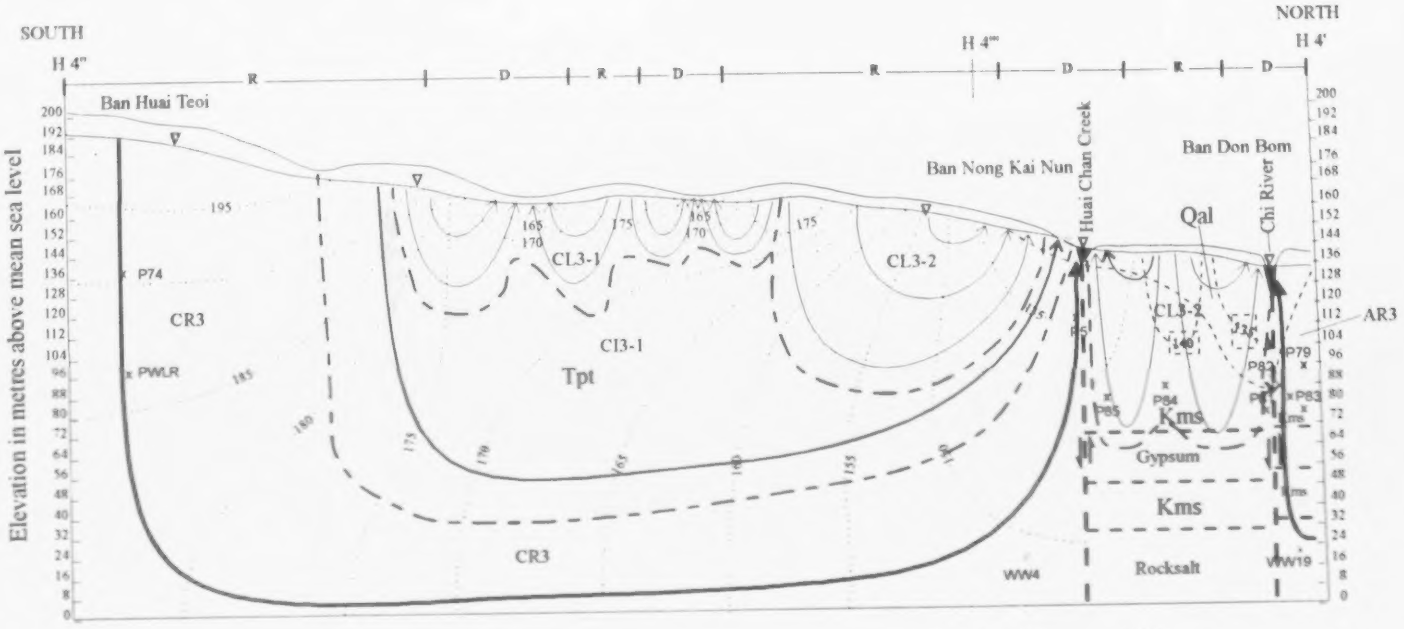

SOUTH
H 4"
NORTH
H 4'
H 4'''
R
D
Elevation in metres above mean sea level
Ban Huai Teoi
Ban Nong Kai Nun
Huai Chan Creek
Ban Don Bom
Chi River
Qal
CR3
CI3-1
CL3-1
CL3-2
Tpt
Kms
Gypsum
Rocksalt
AR3
P74
PWLR
P79
P82
P83
P84
P85
WW4
WW19
195
185
180
175
170
165
160
155
150
140
1000 500 0 1000 m
Vertical exaggeration = 25

Figure 6.3 Hydrogeologic profile H4" - H4'

—160—	Line of equal hydraulic head with elevation above m.s.l. in m.
	Flow paths, directions and systems
→	Local flow(CL3-1)
→	Intermediate flow(CI3-1)
➡	Regional flow(CR3)
- - -	Flow system boundary
～	Land surface
—	Water table
▨	Area of observed flowing wells
R	Recharge area (upward flow)
D	Discharge area (downward flow)
x	Bottom of wells and piezometers
----	Geologic boundary
⇌	Fault
Qsg	Sand and gravel unit
Tpt	Phu Tok unit
Kms	Mahasarakham unit

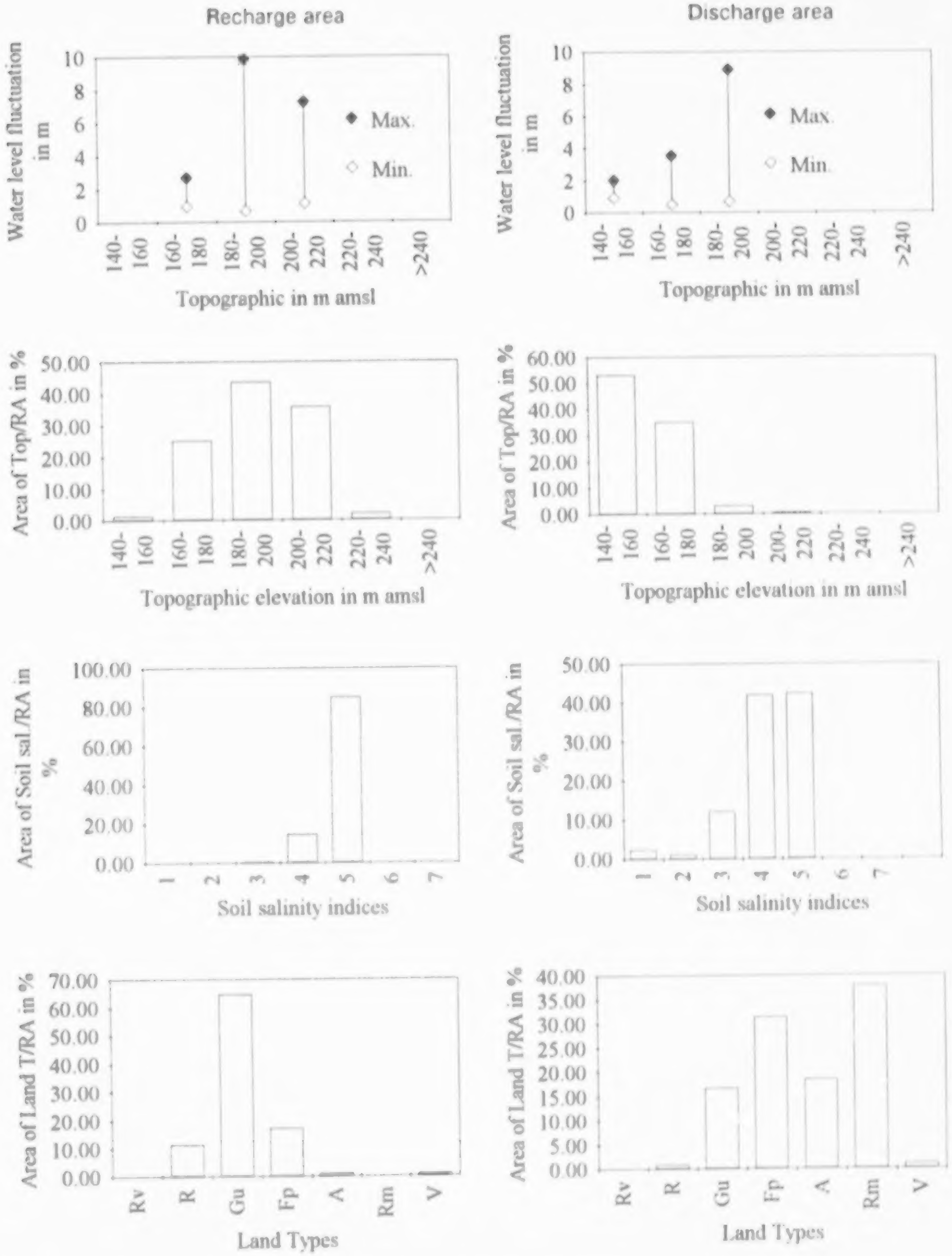
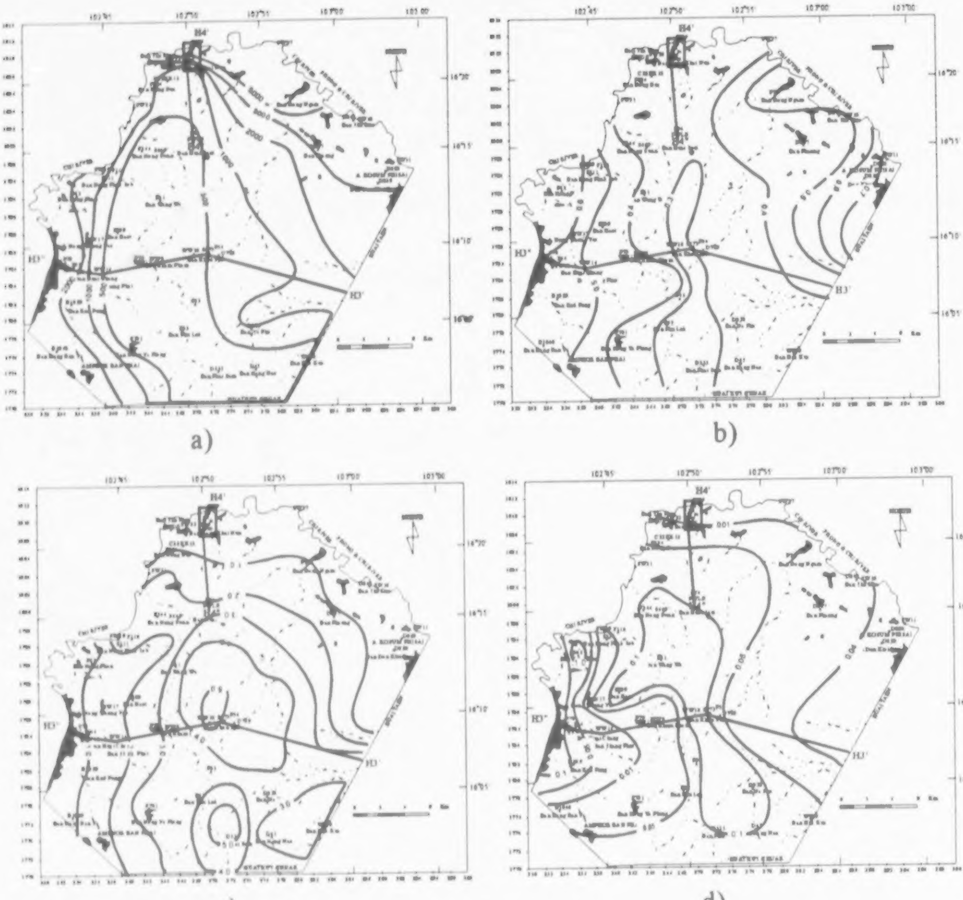


Figure 6.4 Relationship between recharge and discharge areas, water level fluctuations, topographic elevations, soil salinty indices and land types in Hin Tank Hydrogeologic Province



a) b)

c) d)

Figure 6.5 Distribution of TDS and ionic ratios in Hin Tank Hydrogeologic Province

a) TDS contents (mg/l)
b) magnesium to calcium ratio
c) calcium to sodium ratio
d) sulphate to chloride ratio

⋯	Stream
●	Lake or reservoir
H3"___H3'	Line of hydrogeological profile
⊕	Amphoe or district
WW4	Water wells
P1 & SW22	Piezometers and surfacewater
1000	TDS in mg/l

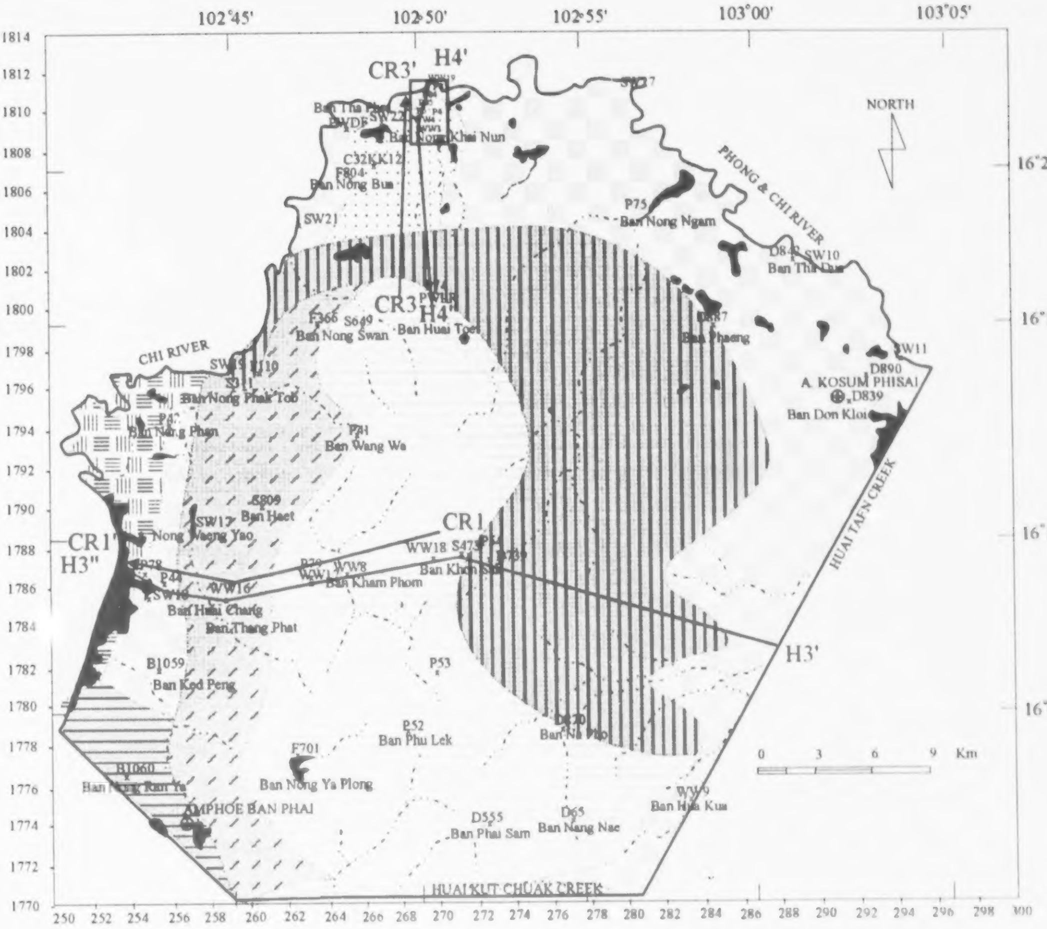
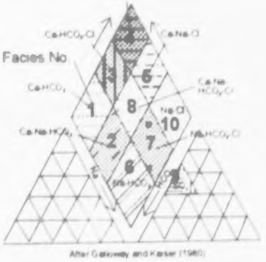

102°45'
102°50'
102°55'
103°00'
103°05'
1814
1812
1810
1808
1806
1804
1802
1800
1798
1796
1794
1792
1790
1788
1786
1784
1782
1780
1778
1776
1774
1772
1770
250
252
254
256
258
260
262
264
266
268
270
272
274
276
278
280
282
284
286
288
290
292
294
296
298
300
16°20'
16°15'
16°10'
16°05'
CR3'
H4'
CR3
H4"
CR1
CR1"
H3"
H3'
NORTH
PHONG & CHI RIVER
CHI RIVER
HUAI TAFN CREEK
HUAI KUT CHUAK CREEK
Ban Tha Hin
Ban Nong Khai Nun
C32KK12
F804
Ban Nong Bua
SW21
SW27
P75
Ban Nong Ngam
D842 SW10
Ban Tha Dua
Ban Huai Toei
F366 S669
Ban Nong Swan
Ban Phaeng
SW11
D890
A. KOSUM PHISAI
D839
Ban Don Kloi
Ban Nong Phak Tob
Ban Nong Phan
Ban Wang Wa
S809
Ban Haet
SW17
Nong Waeng Yao
WW18 S475
WW8
Ban Kham Phom
Ban Khon Sa
P44
WW16
Ban Huai Chang
Ban Thang Phat
B1059
Ban Ked Peng
P53
P52
Ban Phu Lek
D670
Ban Na Pho
F701
Ban Nong Ya Plong
B1060
Ban Nong Kan Ya
AMPHOE BAN PHAI
D555
Ban Phai Sam
D65
Ban Nang Nae
WW9
Ban Hua Kua
0
3
6
9
Km

Figure 6.6 Distribution of hydrochemical facies in Hin Tank Hydrogeologic Province

⋯	Stream
▬	Lake or reservoir
H3"____H3'	Line of hydrogeological profile
⊕	Amphoe or district
WW4	Water wells
P1 & SW12	Piezometers and surface water
CR1 → CR1'	Selected flow path for identifying hydrochemical processes

Hydrochemical classification


Ca-Cl
Ca-HCO3-Cl
Ca-Na-Cl
Facies No
Ca-HCO3
Ca-Na-HCO3-Cl
Na-Cl
Ca-Na-HCO3
Na-HCO3-Cl
Na-HCO3
1
2
3
4
5
6
7
8
9
10

After Galloway and Kaiser (1980)

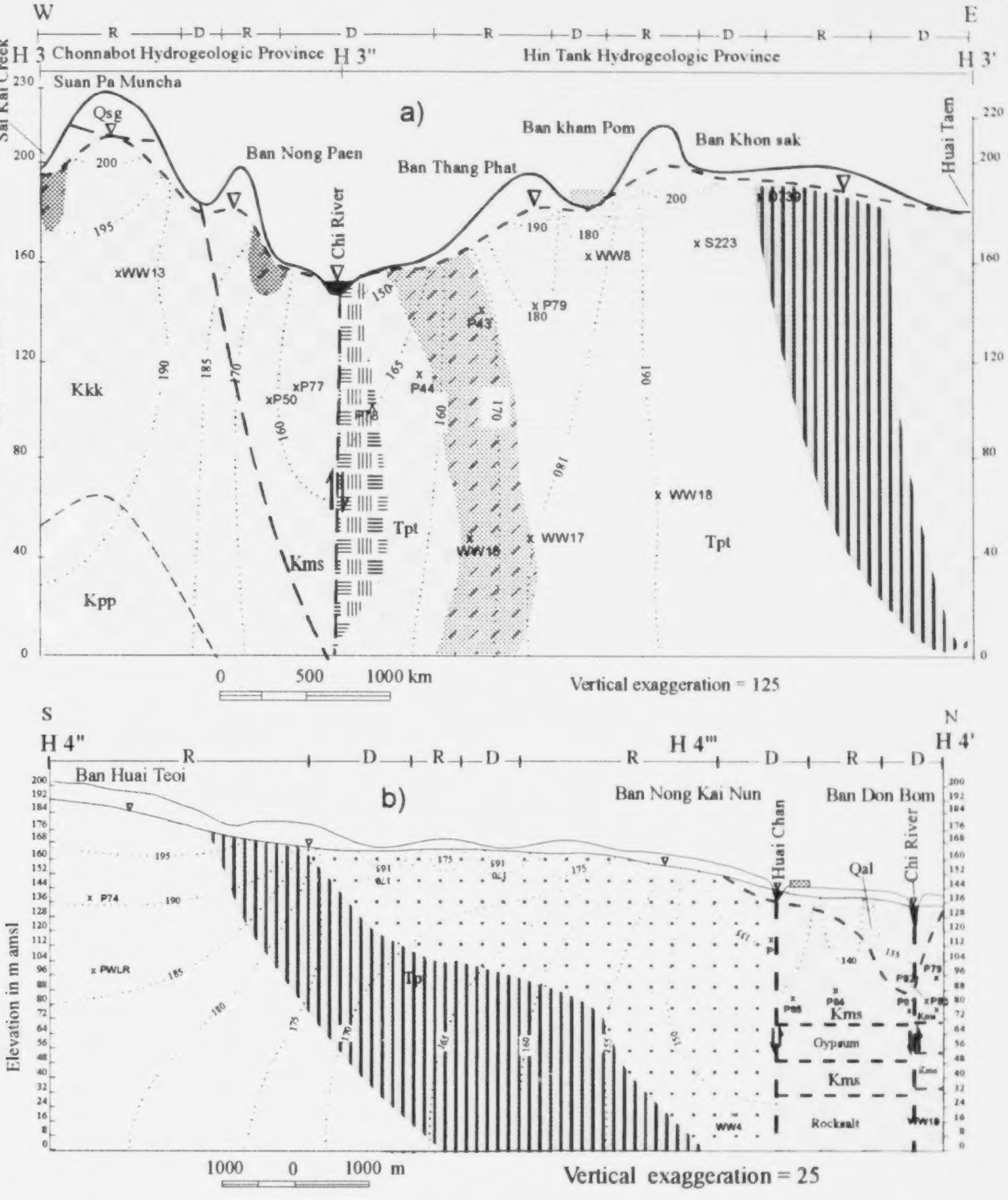

W
E
H 3
Chonnabot Hydrogeologic Province
H 3"
Hin Tank Hydrogeologic Province
H 3'
R
D
Sai Kai Creek
Suan Pa Muncha
Qsg
a)
Ban Nong Paen
Chi River
Ban Thang Phat
Ban kham Pom
Ban Khon sak
Huai Taen
Elevation in m amsl
xWW13
Kkk
Kpp
Kms
Tpt
xP50
xP77
P78
P43
P44
P79
WW8
S223
WW16
WW17
WW18
0
500
1000 km
Vertical exaggeration = 125
S
N
H 4"
H 4'''
H 4'
b)
Ban Huai Teoi
Ban Nong Kai Nun
Ban Don Bom
Huai Chan
Chi River
Qal
P74
PWLR
Tpt
Kms
Gypsum
Rocksalt
WW4
WW16
1000
0
1000 m
Vertical exaggeration = 25

Figure 6.7 Hydrogeologic profiles along a) H3- H3' and b) H4"-H4'

···160··· Line of equal hydraulic head (5 m contour interval)

– –∇– – Water table

x Bottom of wells and piezometers

Ground surface

▨ Area of observed flowing wells

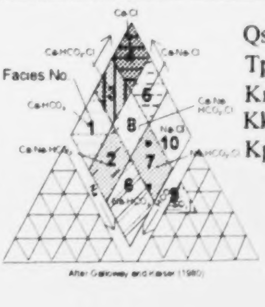
R Recharge area (downward flow)

D Discharge area (upward flow)

⇄ Concealed fault

– – – – – Hydrogeologic unit boundary

Hydrochemical facies classification


CaCl
CaHCO3Cl
CaNaCl
Facies No
CaHCO3
CaNa HCO3Cl
NaCl
CaNaHCO3
NaHCO3Cl
NaHCO3
1
2
3
4
5
6
7
8
9
10

After Galloway and Kaiser (1980)

Qsg Sand and gravel unit
Tpt Phu Tok unit
Kms Mahasarakam unit
Kkk Khok Kruat unit
Kpp Phu Phan unit

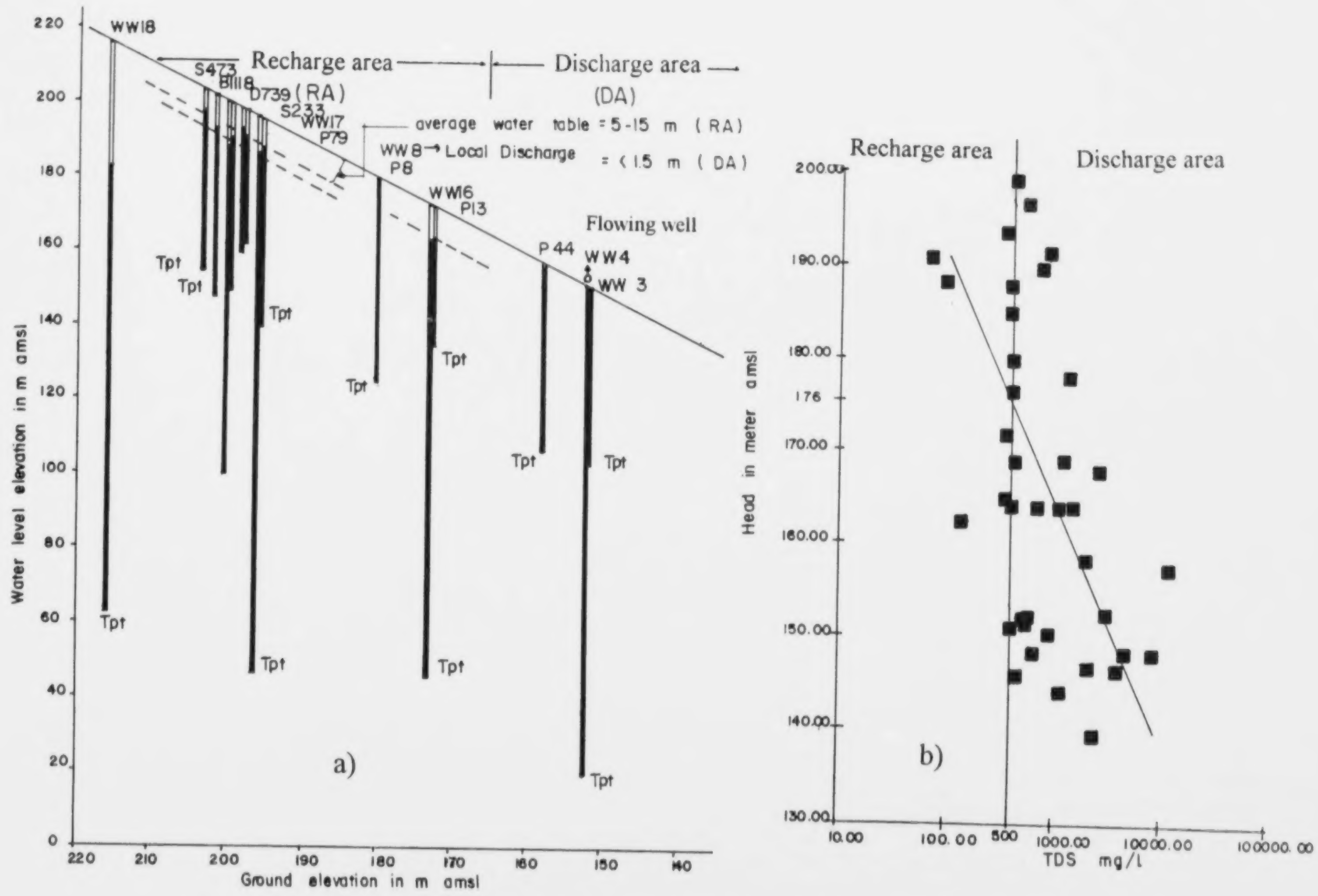


Figure 6.8 Relationship between a) well depts, water levels and ground surface elevations and b) Total dissolved solids and hydraulic heads in Hin Tank Hydrogeologic Province

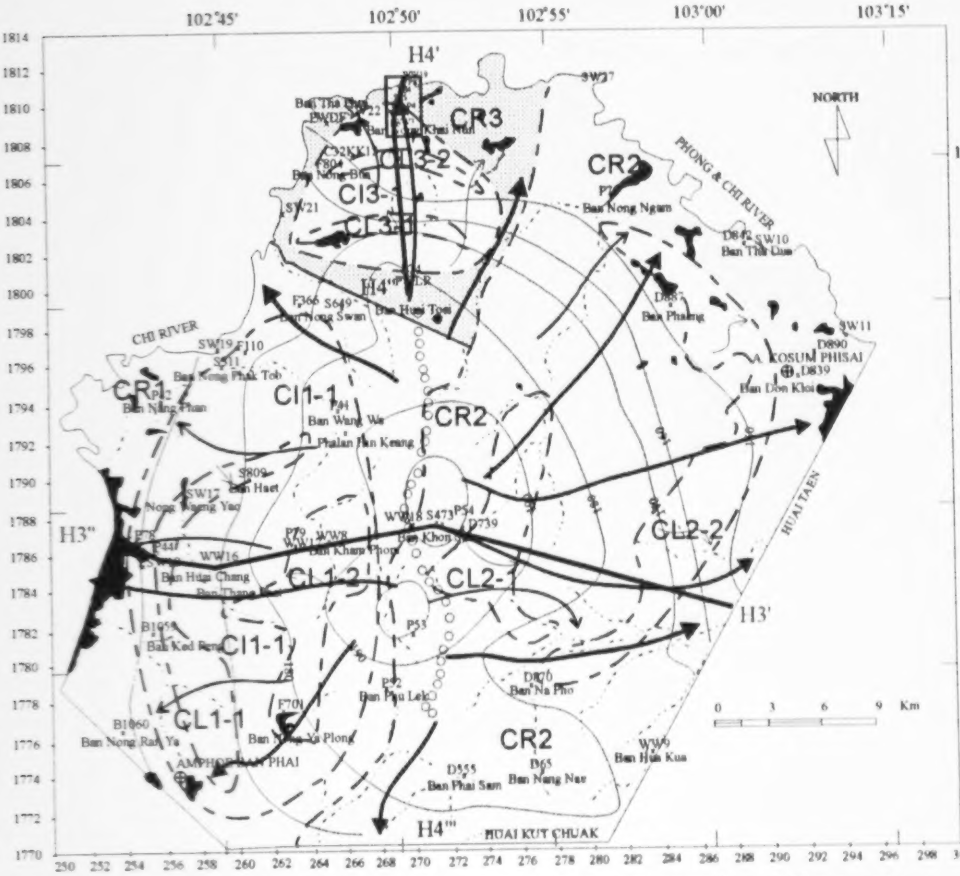
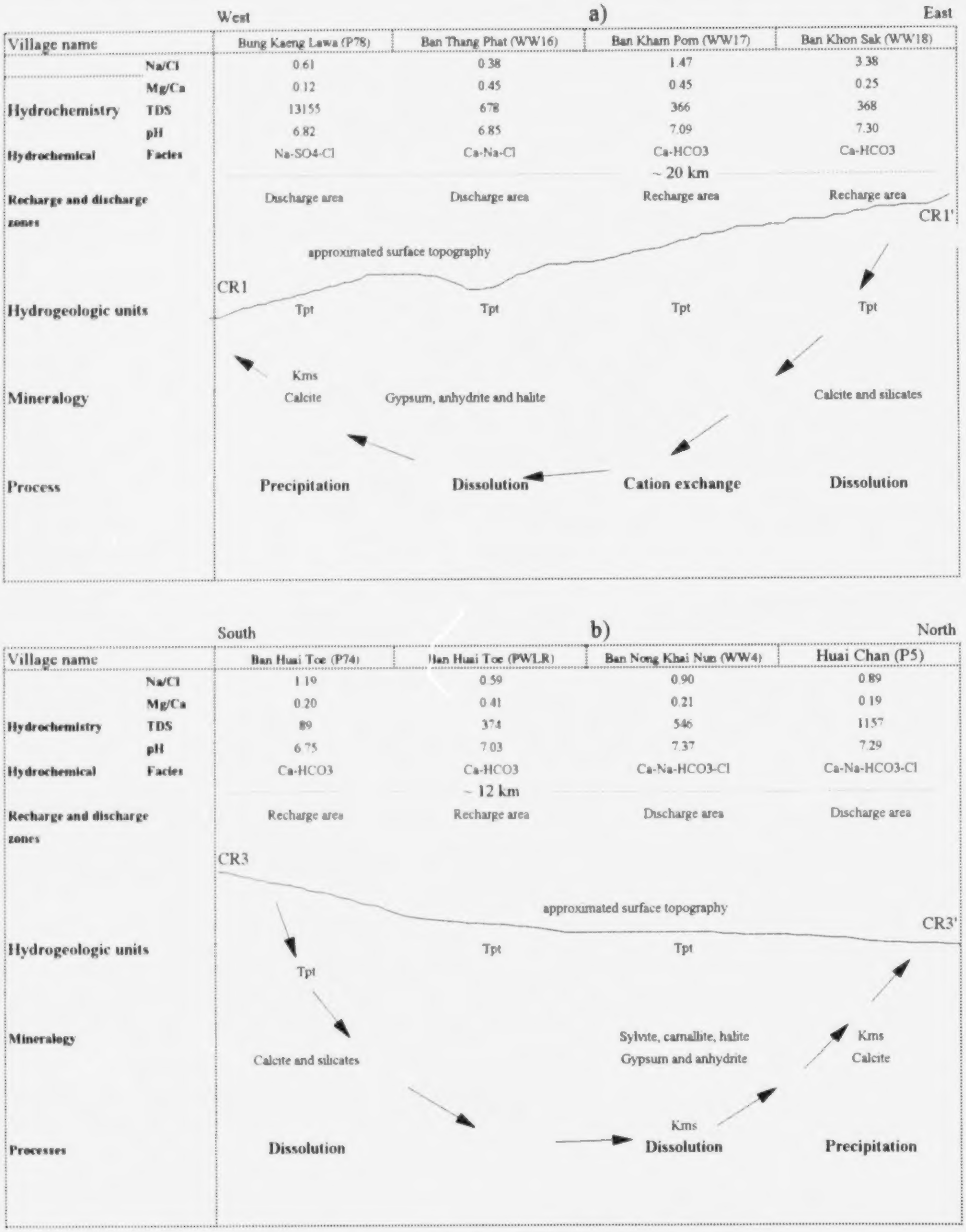

102°45'
102°50'
102°55'
103°00'
103°15'
16°20'
16°15'
16°10'
16°05'
NORTH
H4'
H4''
H4'''
H3'
H3''
CR1
CR2
CR3
CI1-1
CI3-1
CL1-1
CL1-2
CL2-1
CL2-2
CL3-1
CL3-2
CHI RIVER
PHONG & CHI RIVER
HUAI TAEN
HUAI KUT CHUAK
A. KOSUM PHISAI
AMPHOE BAN PHAI
Ban Nong Ngam
Ban Tha Dua
Ban Phaeng
Ban Don Khoi
Ban Huai Teoi
Ban Nong Swan
Ban Nong Phak Tob
Ban Nong Phan
Ban Wang Wa
Phalan Han Keang
Ban Haet
Nong Waeng Yao
Ban Hua Chang
Ban Thang
Ban Kham Phom
Ban Khon Sak
Ban Ked Bong
Ban Nong Rai Ya
Ban Nong Ya Plong
Ban Phu Lek
Ban Na Pho
Ban Phai Sam
Ban Nong Nae
Ban Hua Kua
Ban Nong Khai Nun
Ban Nong Bua
0 3 6 9 Km
1770 1772 1774 1776 1778 1780 1782 1784 1786 1788 1790 1792 1794 1796 1798 1800 1802 1804 1806 1808 1810 1812 1814
250 252 254 256 258 260 262 264 266 268 270 272 274 276 278 280 282 284 286 288 290 292 294 296 298 300

Figure 6.9 Distribution of hydraulic heads, groundwater flow paths and flow systems in Hin Tank Hydrogeologic Province

Stream
Lake or reservoir
H3''——H3' Line of hydrogeological profile
⊕ Amphoe or district
WW4 Water wells
P1 & SW22 Piezometers and surface water
○○○○○ Surface and groundwater divide
—160— Equipotential line
(10 m contour inteval)
Flow path and direction
→ Local
→ Intermediate
→ Regional
— — — Flow system boundary

Flow Systems
Regional
CR1 Ban Phai
CR2 Kosum Phisai
CR3 Huai Teoi
Intermediate
CI1-1 Thang Phat
CI3-1 Ban Nong Khai Nun
Local
CL1-1 Ban Hua Chang
CL1-2 Ban Kham Pom
CL2-1 Ban Khon Sak
CL2-2 Huai Taen
CL3-1 Hin Tank
CL3-2 Tha Phra (CL3-2)


a)
West
East
~ 20 km
approximated surface topography
CR1
CR1'
b)
South
North
~ 12 km
approximated surface topography
CR3
CR3'

a)

Village name		Bung Kaeng Lawa (P78)	Ban Thang Phat (WW16)	Ban Kham Pom (WW17)	Ban Khon Sak (WW18)
Hydrochemistry	Na/Cl	0.61	0.38	1.47	3.38
	Mg/Ca	0.12	0.45	0.45	0.25
	TDS	13155	678	366	368
	pH	6.82	6.85	7.09	7.30
Hydrochemical	Facies	Na-SO4-Cl	Ca-Na-Cl	Ca-HCO3	Ca-HCO3
Recharge and discharge zones		Discharge area	Discharge area	Recharge area	Recharge area
Hydrogeologic units		Tpt	Tpt	Tpt	Tpt
Mineralogy		Kms Calcite	Gypsum, anhydrite and halite		Calcite and silicates
Process		Precipitation	Dissolution	Cation exchange	Dissolution

b)

Village name		Ban Huai Toe (P74)	Ban Huai Toe (PWLR)	Ban Nong Khai Nun (WW4)	Huai Chan (P5)
Hydrochemistry	Na/Cl	1.19	0.59	0.90	0.89
	Mg/Ca	0.20	0.41	0.21	0.19
	TDS	89	374	546	1157
	pH	6.75	7.03	7.37	7.29
Hydrochemical	Facies	Ca-HCO3	Ca-HCO3	Ca-Na-HCO3-Cl	Ca-Na-HCO3-Cl
Recharge and discharge zones		Recharge area	Recharge area	Discharge area	Discharge area
Hydrogeologic units		Tpt	Tpt	Tpt	
Mineralogy		Calcite and silicates		Sylvite, carnallite, halite Gypsum and anhydrite	Kms Calcite
Processes		Dissolution		Kms Dissolution	Precipitation

Figure 6.10 Schematic diagram showing hydrochemical processes along
a) CR1-CR1' flow path for Ban Phai regional flow system
b) CR3-CR3' flow path forHuai Toei regional flow system
in regional groundwater flow systems in Hin Tank Hydrogeologic Province

→ Flow line
Tpt = Tertiary Phu Tok hydrogeologic unit
Kms = Cretaceous Mahasarakham hydrogeologic unit

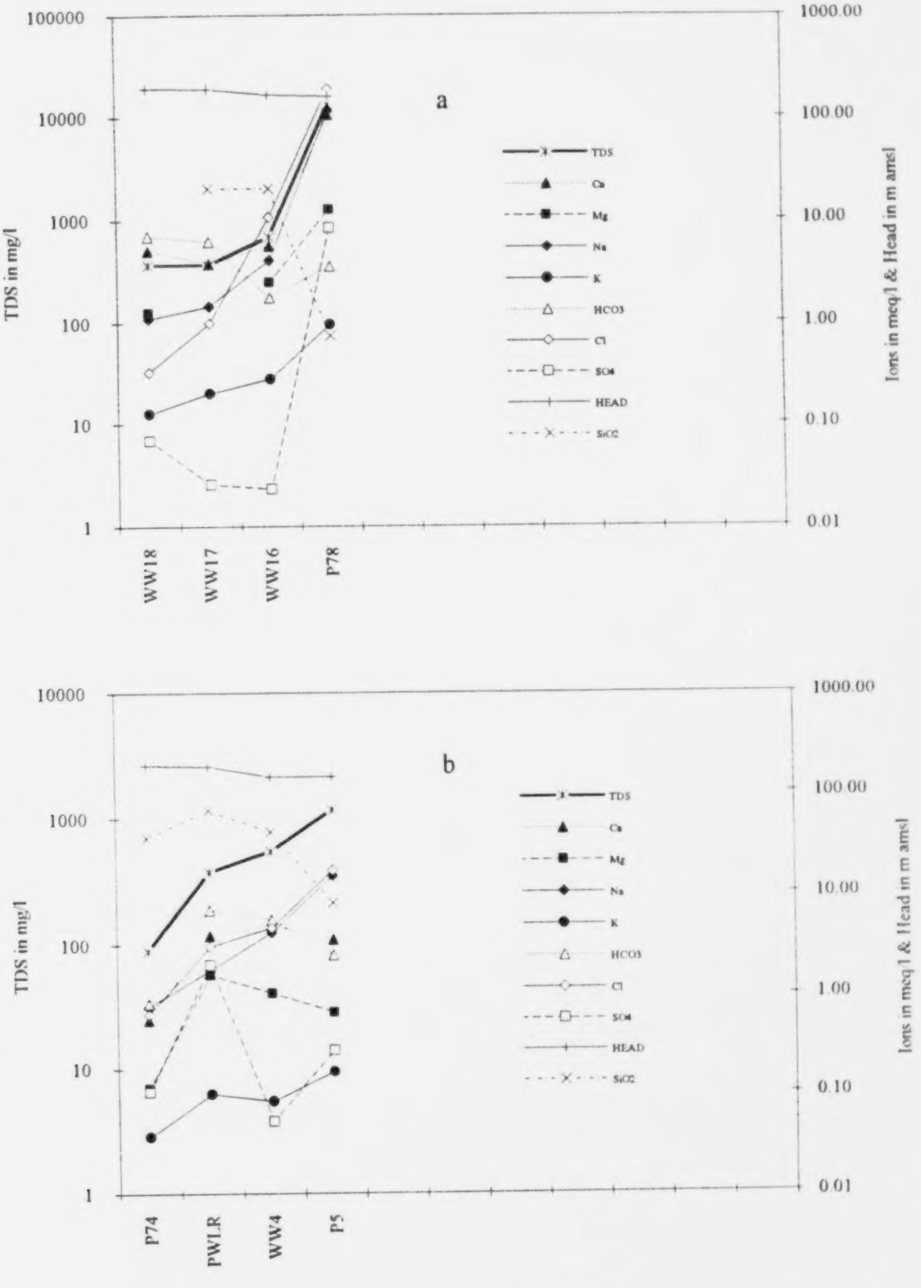


Figure 6.11 Concentrations of individual major ions for selected flow paths in Hin Tank
a) CR1-CR1' flow path for Ban Phai regional flow system (CR1),
b) CR3-CR3' flow path for Huai Toe regional flow system (CR3)

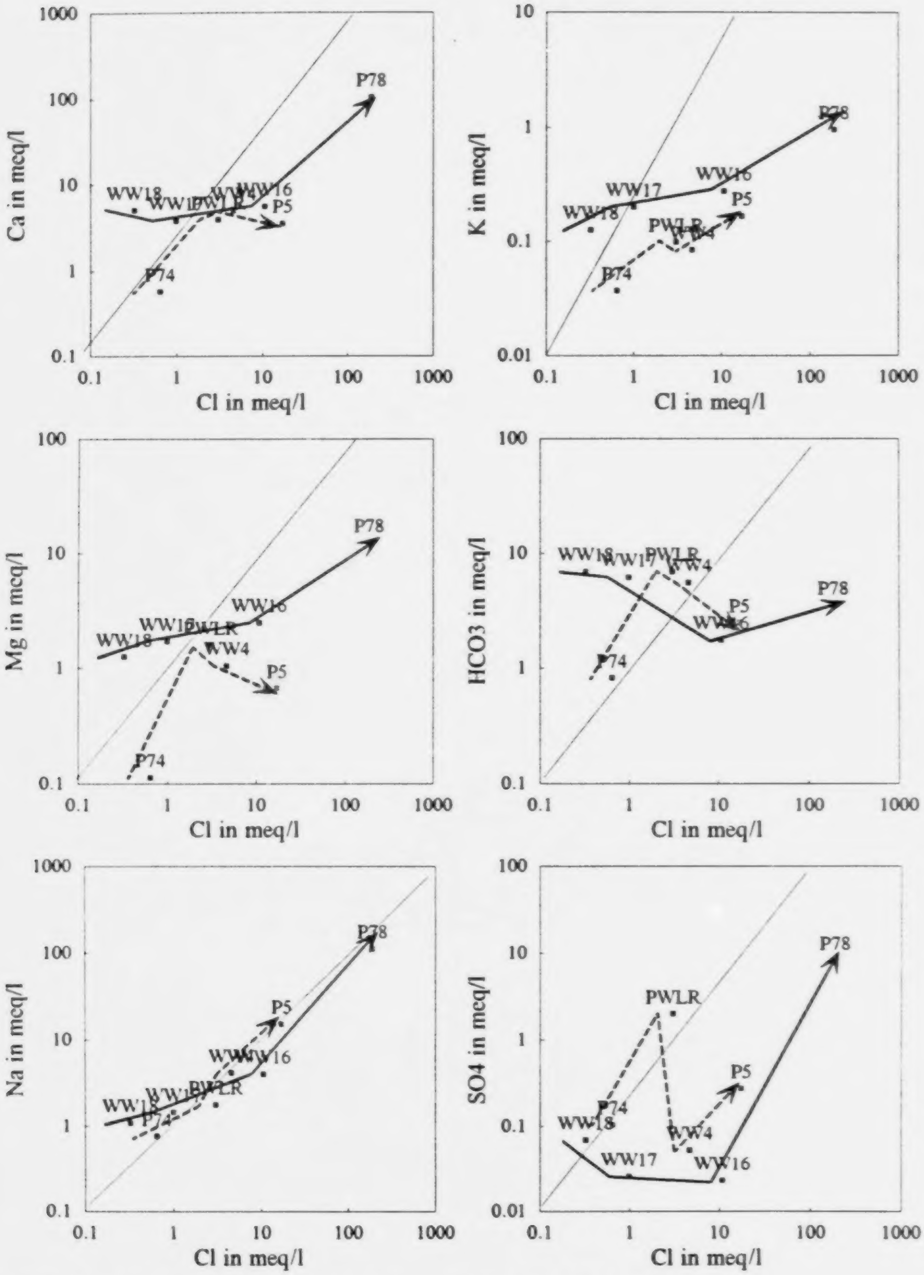


Figure 6.12 Concentrations of individual major ions related to chloride ion along
CR1-CR1' flow path for Ban Phai regional flow system (solid arrow)
CR3-CR3' flow path for Huai Toei regional flow system (dash arrow)
in Hin Tank Hydrogeologic Province

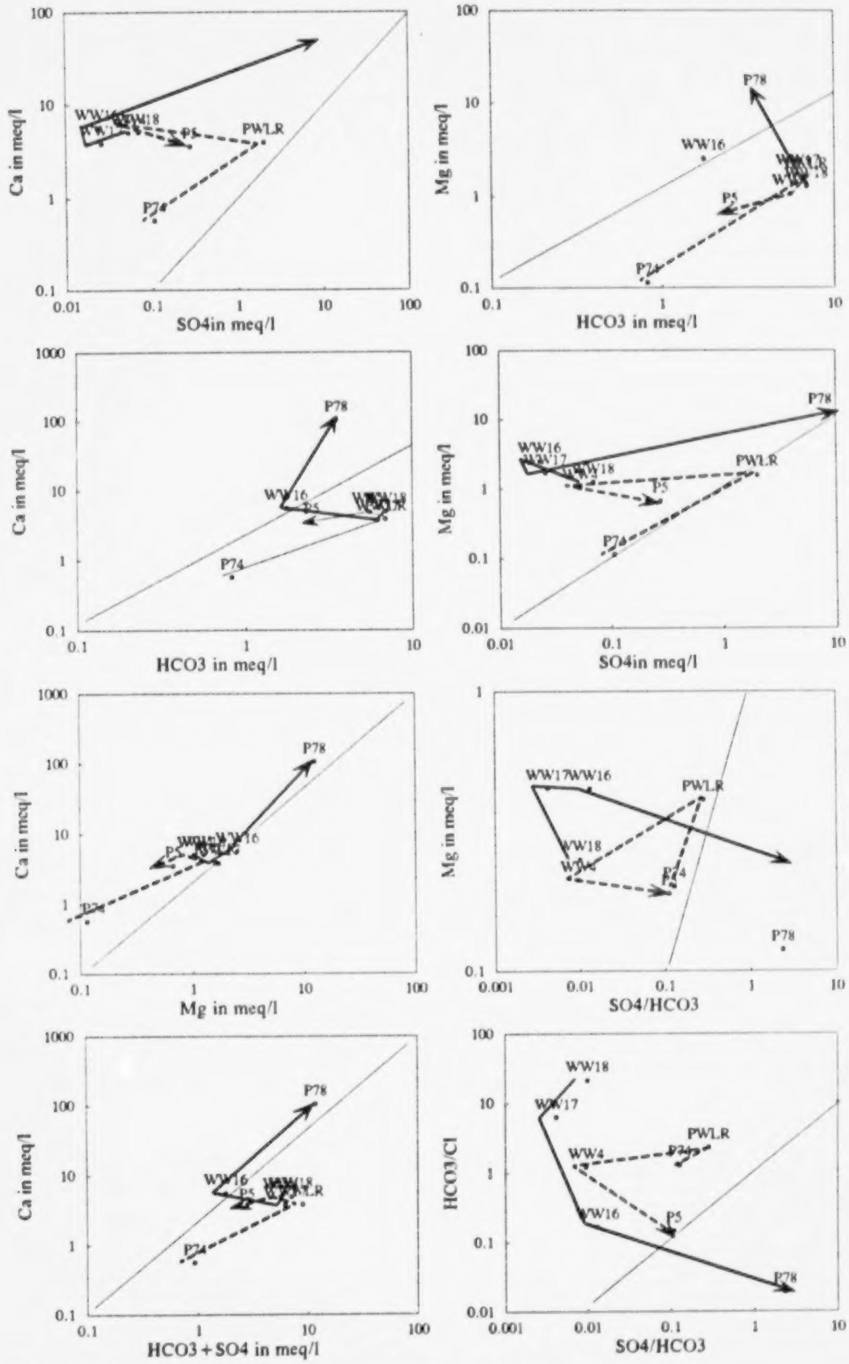


Figure 6.13 Relationship of ionic parameters along
CR1-CR1' flow path for Ban Phai regional flow system (solid arrow)
CR3-CR3' flow path for Huai Toei regional flow system (dash arrow)
in Hin Tank Hydrogeologic Province

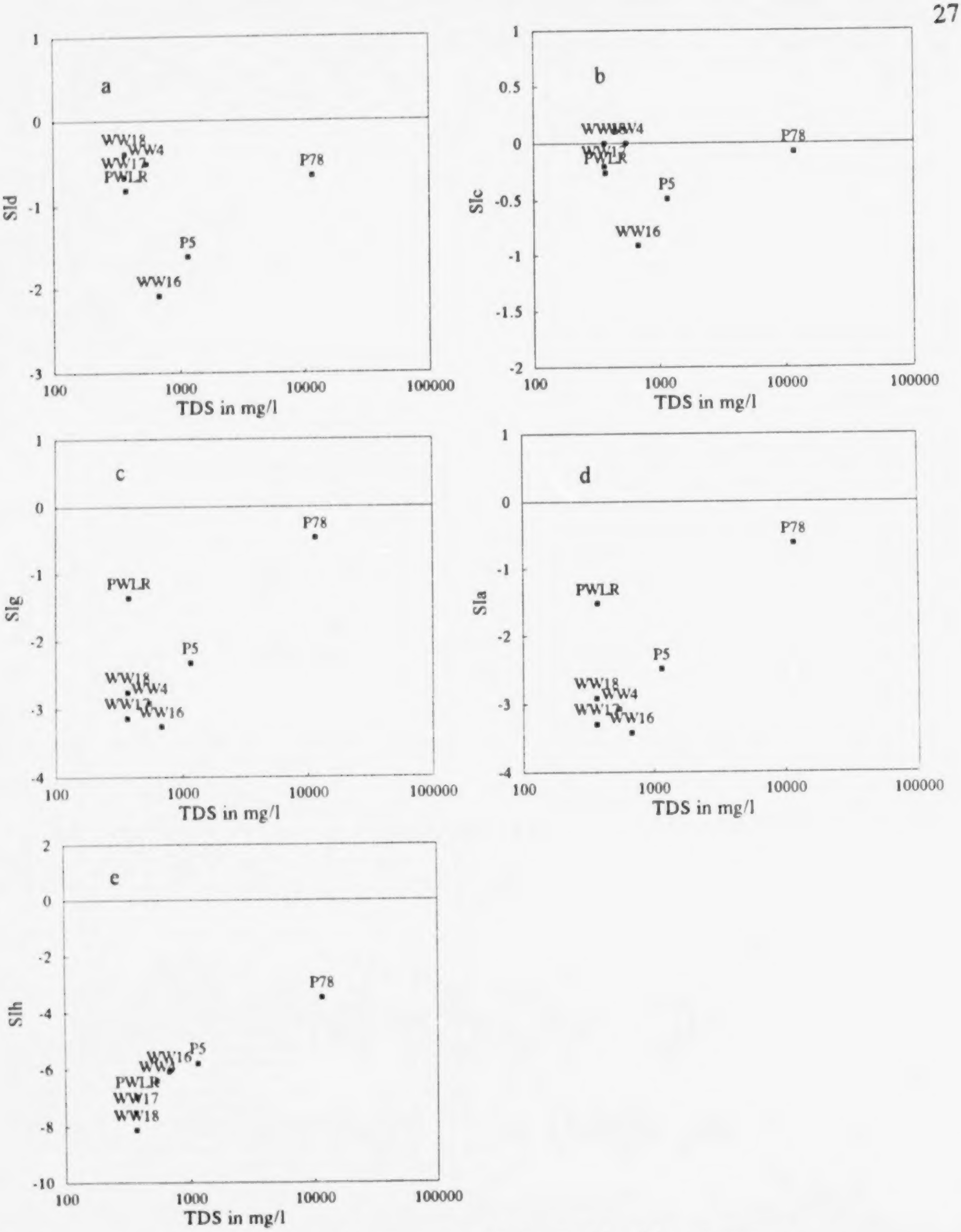


Figure 6.14 Saturation indices with respect to a) dolomite, b) calcite, c) gypsum, d) anhydrite and e) halite, as a function of TDS contents in groundwater along the flow paths in Hin Tank Hydrogeologic Province

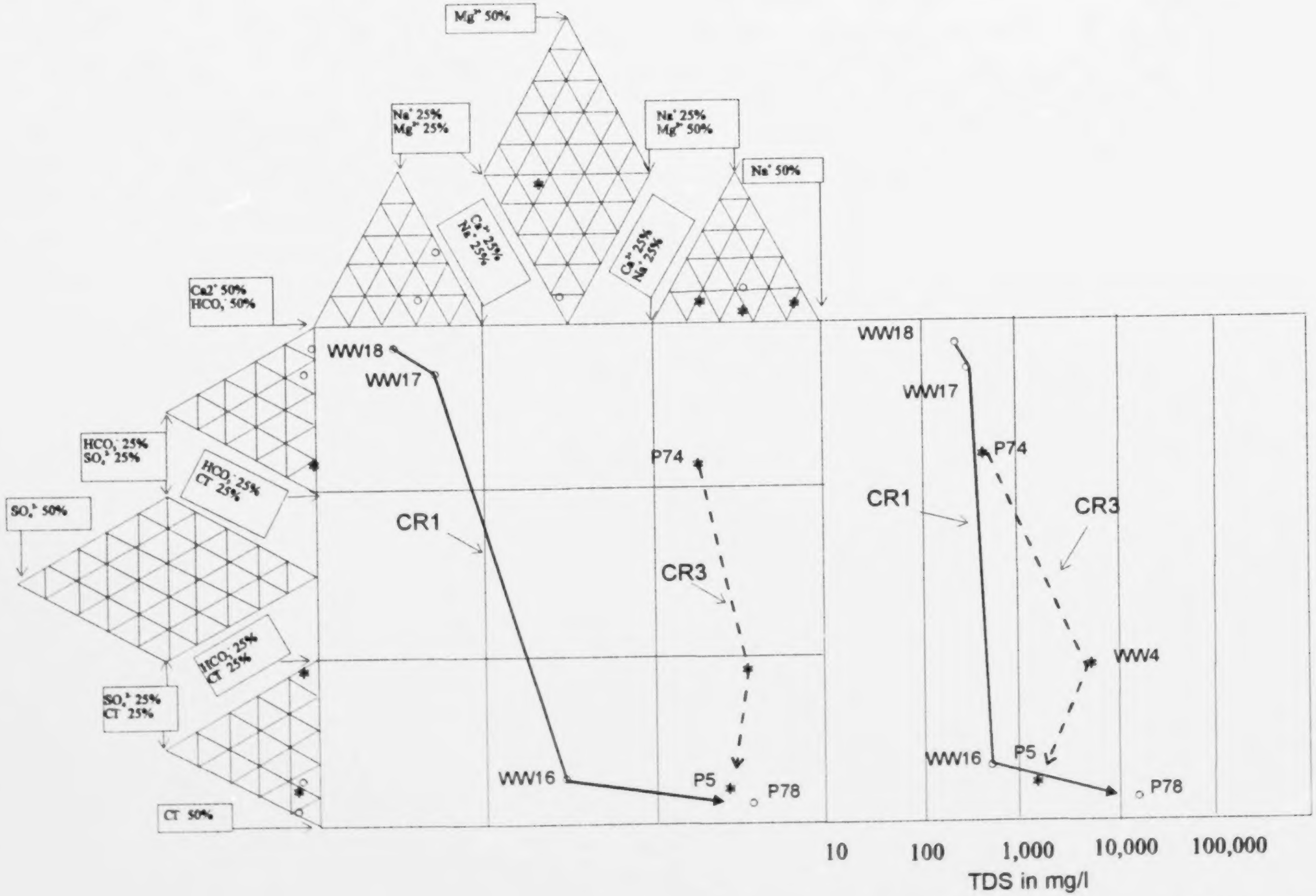


Figure 6.15 Expanded Durov diagram of selected groundwater samples along the flow paths CR1 and CR3 in Hin Tank Hydrogeologic Province

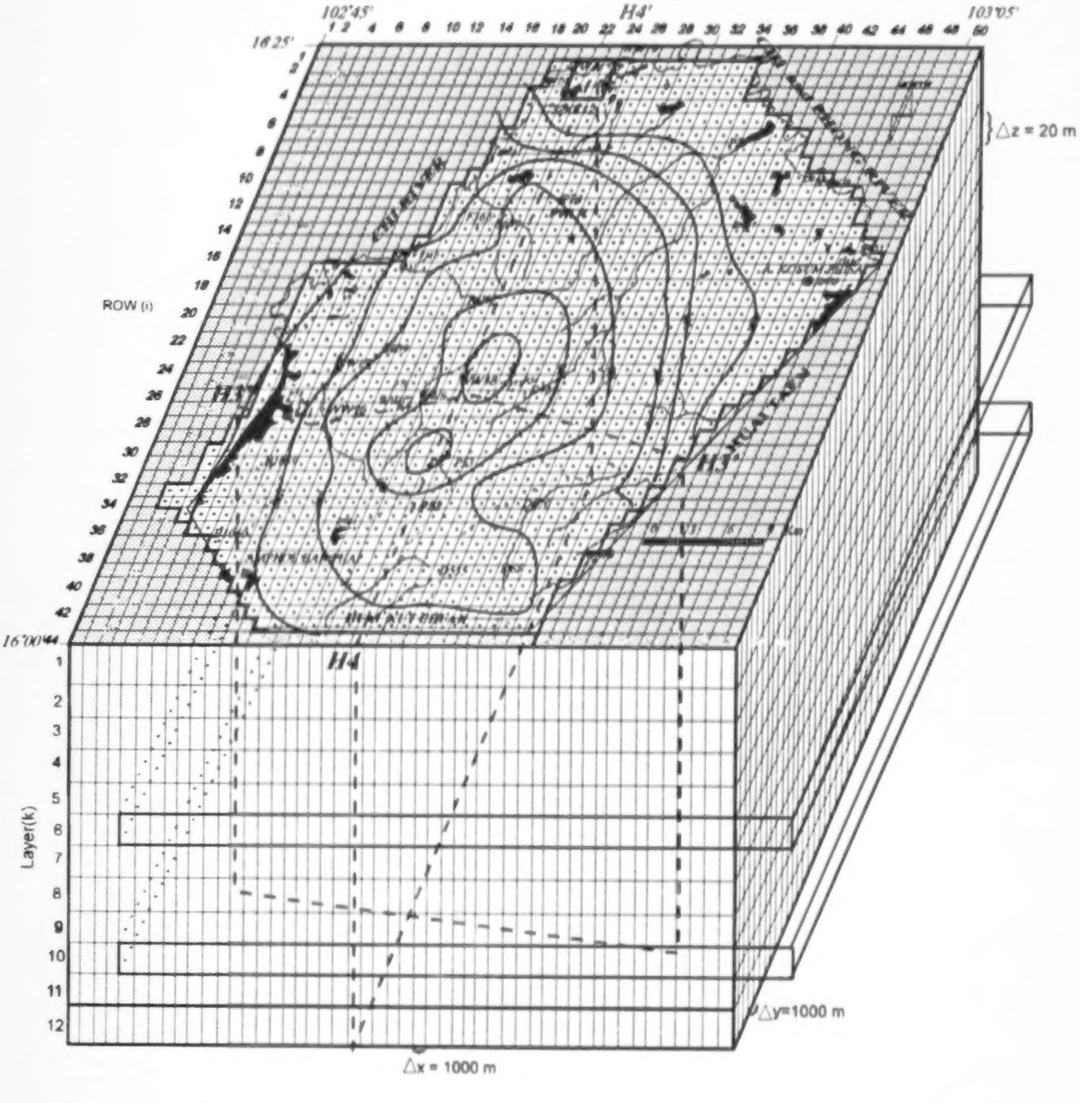

COLUMN(j)
102°45'
H4'
103°05'
16°25'
ROW (i)
16°00'
H3'
H3"
H4
Layer(k)
Δz = 20 m
Δy=1000 m
Δx = 1000 m

Figure 6.16 Schematic diagram of a full three-dimensional model for Hin Tank Hydrogeologic Province

Stream	
Lake or reservoir	
H3" H3'	Line of hydrogeological profile
⊕	Amphoe or district
WW4	Water wells
P1 & SW22	Piezometers and surface water
	Modelled boundary
⊡	Block-centered grid for active cell
☐	Incative cell

COLUMN (J)

ROW (I)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	3.47	3.47	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	3.47	3.47	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	3	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	5	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	0	0	0
16	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	0	0
17	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	3	0
18	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	3.47	0	0
19	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	0	0	0
20	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	0	0	0	0
21	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	0	0	0	0
22	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	0	0	0	0	0
23	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	3.47	0	0	0	0	0
24	0	0	0	0	3.47	3.47	3.47	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	0	0	0	0	0	0
25	0	0	0	0	3.47	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	0	0	0	0	0	0
26	0	0	0	0	0	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	0	0	0	0	0	0	0
27	0	0	0	0	0	3.47	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	0	0	0	0	0	0	0
28	0	0	0	0	0	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	0	0	0	0	0	0	0	0
29	0	0	0	0	3.47	3.47	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	0	0	0	0	0	0	0	0
30	0	0	0	3.47	3.47	1	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	0	0	0	0	0	0	0	0	0
31	0	0	0	3.47	3.47	1	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0	0
32	0	0	0	3.47	3.47	1	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	3.47	3.47	1	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0
34	0	3.47	3.47	3.47	3.47	1	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0	0
35	0	3.47	3.47	3.47	3.47	1	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	3.47	3.47	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	3.47	3.47	1	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	3.47	1	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 6.17a Final input assigned horizontal hydraulic conductivities of aquifers for Hin Tank Hydrogeologic Province (model layer 5). The unit of Kh is m/s x E-05

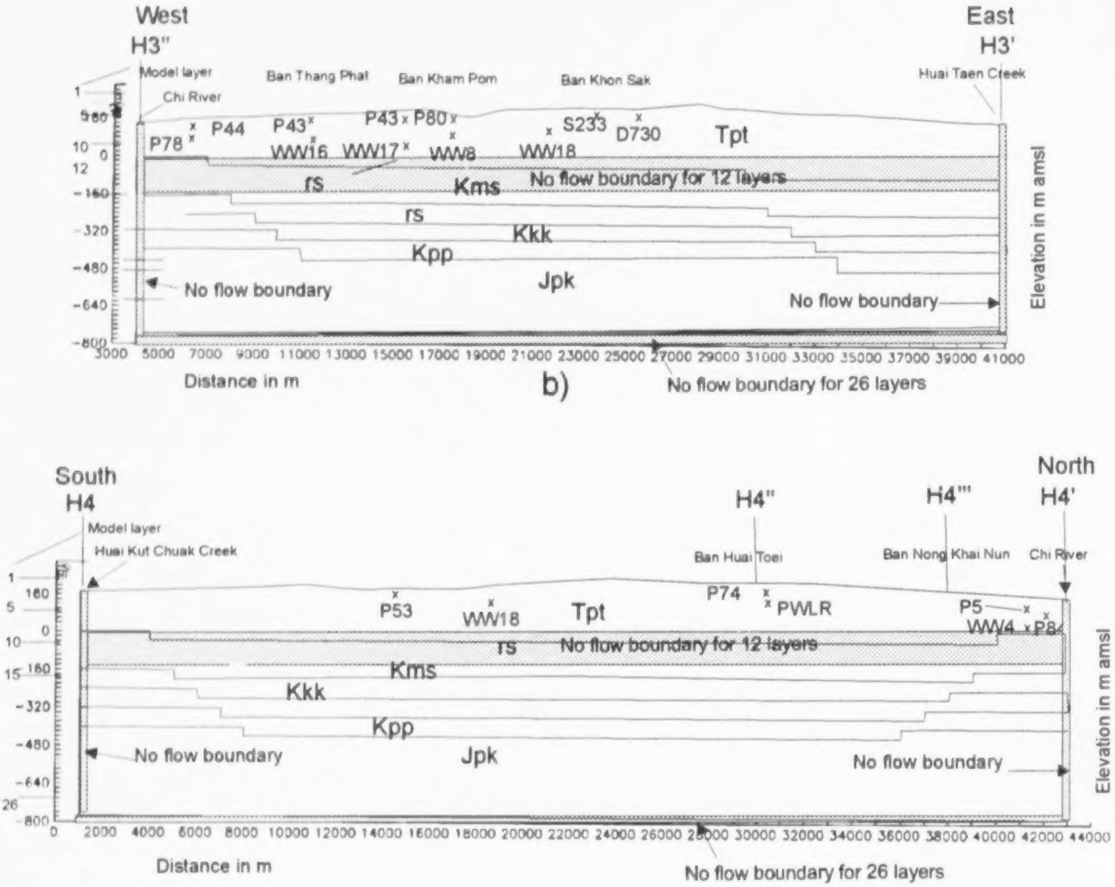

West
H3''
East
H3'
Model layer
Chi River
Ban Thang Phat
Ban Kham Pom
Ban Khon Sak
Huai Taen Creek
P78
P44
P43
WW16
WW17
P43
P80
WW8
WW18
S233
D730
Tpt
rs
Kms
No flow boundary for 12 layers
rs
Kkk
Kpp
Jpk
No flow boundary
No flow boundary
Elevation in m amsl
Distance in m
No flow boundary for 26 layers
b)
South
H4
H4''
H4'''
North
H4'
Model layer
Huai Kut Chuak Creek
Ban Huai Toei
Ban Nong Khai Nun
Chi River
P53
WW18
Tpt
P74
PWLR
P5
WW4
P84
rs
No flow boundary for 12 layers
Kms
Kkk
Kpp
Jpk
No flow boundary
No flow boundary
Elevation in m amsl
Distance in m
No flow boundary for 26 layers
c)

Figure 6.17 Final adjusted horizontal and vertical hydraulic conductivites of aquifers and aquitards for Hin Tank Hydrogeologic Province b) along H3-H3' and c) along H4-H4'

Hydrogeologic unit	Kx = Ky m/s ($x10^{-6}$)	Kz m/s ($x10^{-7}$)	Kx/Kz
Tpt	11.6-25.5	0.12-0.06	100.0-30
Kms	1.16-8.10	0.11-0.58	10.0-14.0
Kkk	0.11-0.58	0.02-1.16	1.0-50.0
rs	0.01-0.05	0.16-0.58	1.0
Kpp	2.31-3.70	2.31-0.11	1.0-32.0
Jpk	0.11-0.57	0.11	1.0-5.0

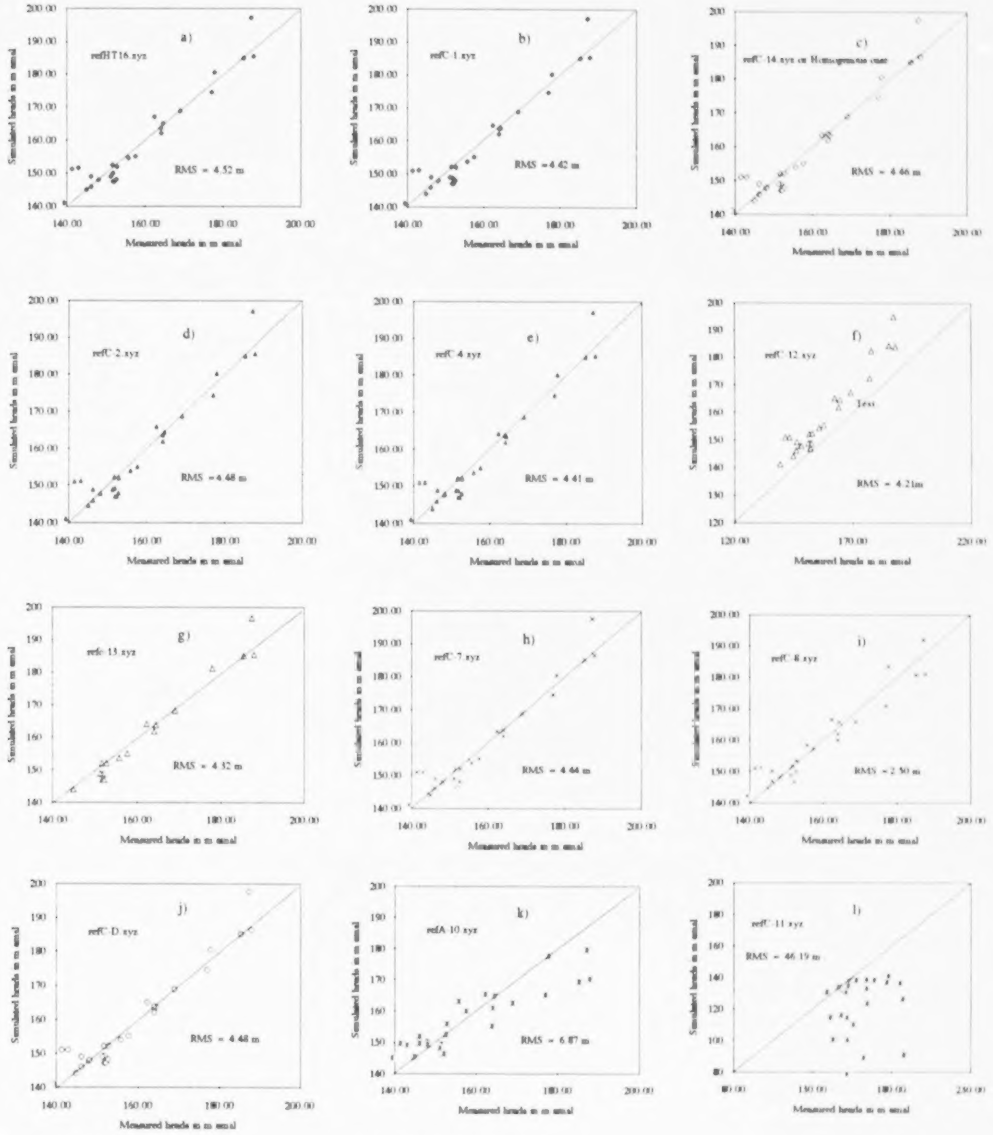


Figure 6.18 Linear regression between measured and simulated hydraulic heads in Hin Tank Hydrogeologic Province , RMS = Root mean squared error

Set#1 a) to b) Bottom boundary variation

a) For 27 Layers the bottom layer at -320 m amsl
b) For 12 Layers the bottom layer at 0.0 m amsl

Set# 2 c) to e) horizontal hydraulic conductivity variation
c) Homogenous case Kx=Ky=Kz=1.16E-05 m/s
d) Kx=10xKy
e) Kx= 0.1xKy

Set# 3 f) to g) Increase and decrease Kx values for twice (Kx=Ky)
f) Kx = 2Ky
Set# 4 g) Kx=0.5 Ky
h) to l) Vertical hydraulic conductivity variation (Kx=Ky)
h) Vz=1E-1Kx i) Vz=1E-2Kx
j) Vz= 1E-1 to 1E-2Kx k) Vz=1E-4Kx
l) Vz= 1E-5Kx

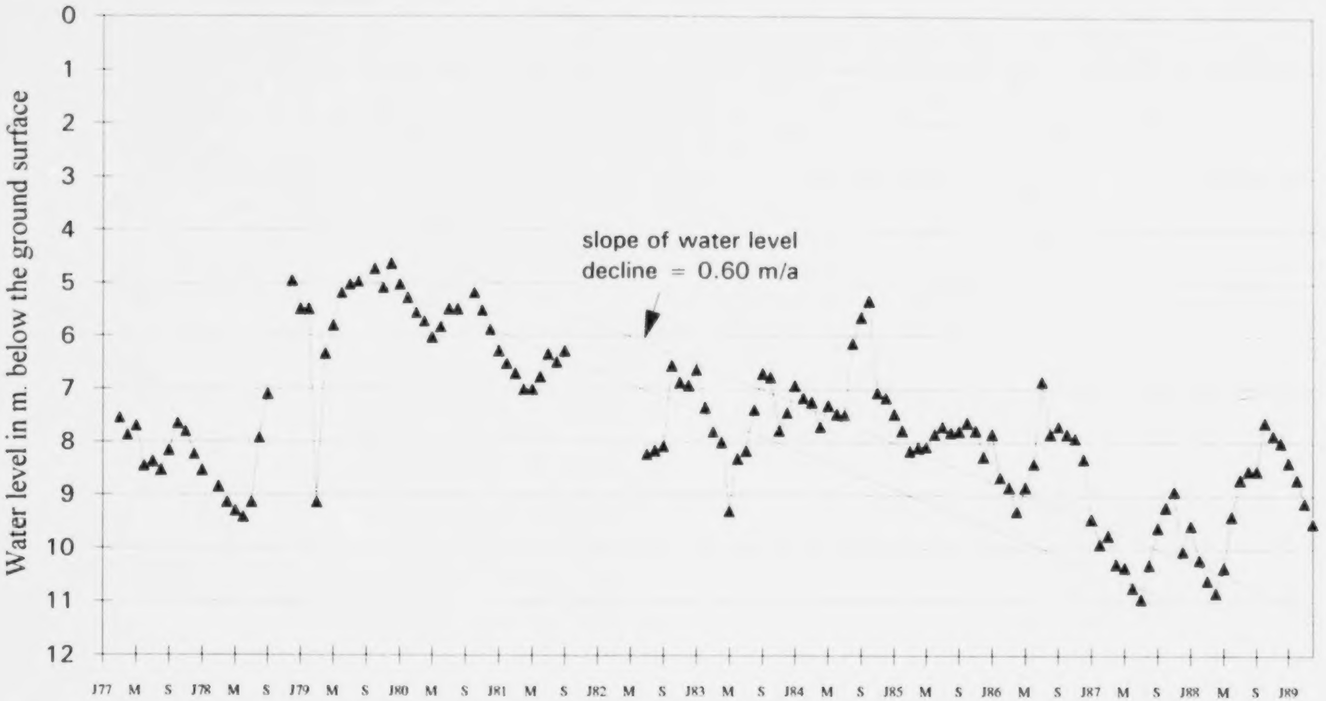


Figure 6.19 Water level fluctuations in well C32KK12 (1977-1989), Tha Phra, Khon Kaen, N.E. Thailand (monitered by Groundwater Division, 1989)

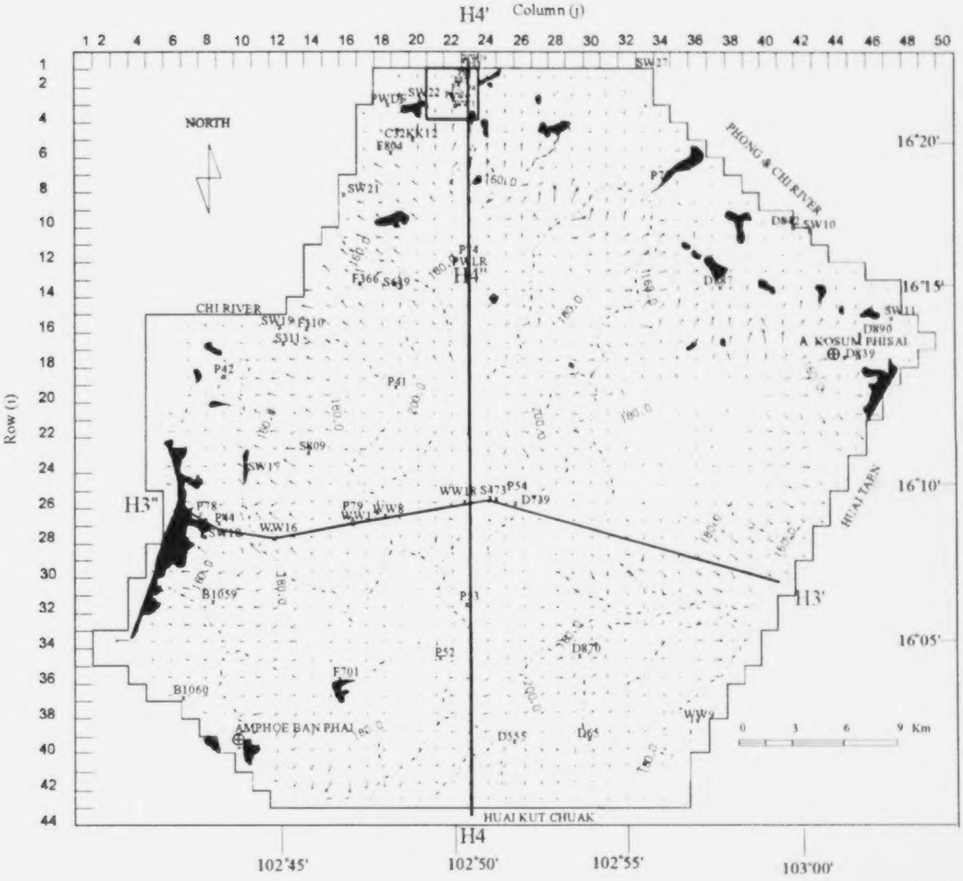

H4'
Column (j)
1 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Row (i)
1 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
NORTH
SW27
PWD8
SW22
CP2KK12
F804
SW21
P14
PWLR
H4"
F366
S439
CHI RIVER
SW19
F310
S311
P42
P41
S809
SW15
H3"
P78
P84
SW18
W.W16
P79
WW17
WW8
WW18
S473
P54
D739
B1059
P33
P52
D870
F701
B1060
AMPHOE BAN PHAI
D555
D65
WW9
P7
PHONG & CHI RIVER
D842
SW10
D857
SW11
D890
A. KOSUM PHISAI
D939
HUAI TARN
H3'
16°20'
16°15'
16°10'
16°05'
160.0
180.0
200.0
0 3 6 9 Km
HUAI KUT CHUAK
H4
102°45'
102°50'
102°55'
103°00'

Figure 6.20a Distribution of simulated heads and vectors of simulated horizontal groundwater flux for model layer 6 of Hin Tank Hydrogeologic Province

Stream

Lake or reservoir

H3"—— H3' Line of hydrogeological profile

⊕ Amphoe or district

WW4 Water wells

P1 & SW22 Piezometers and surface water

4.0×10^{-7} in m/s

180 Equipotential line of simulated hydraulic heads in m amsl

Modeled boundary

Ban Nong Khai Nun

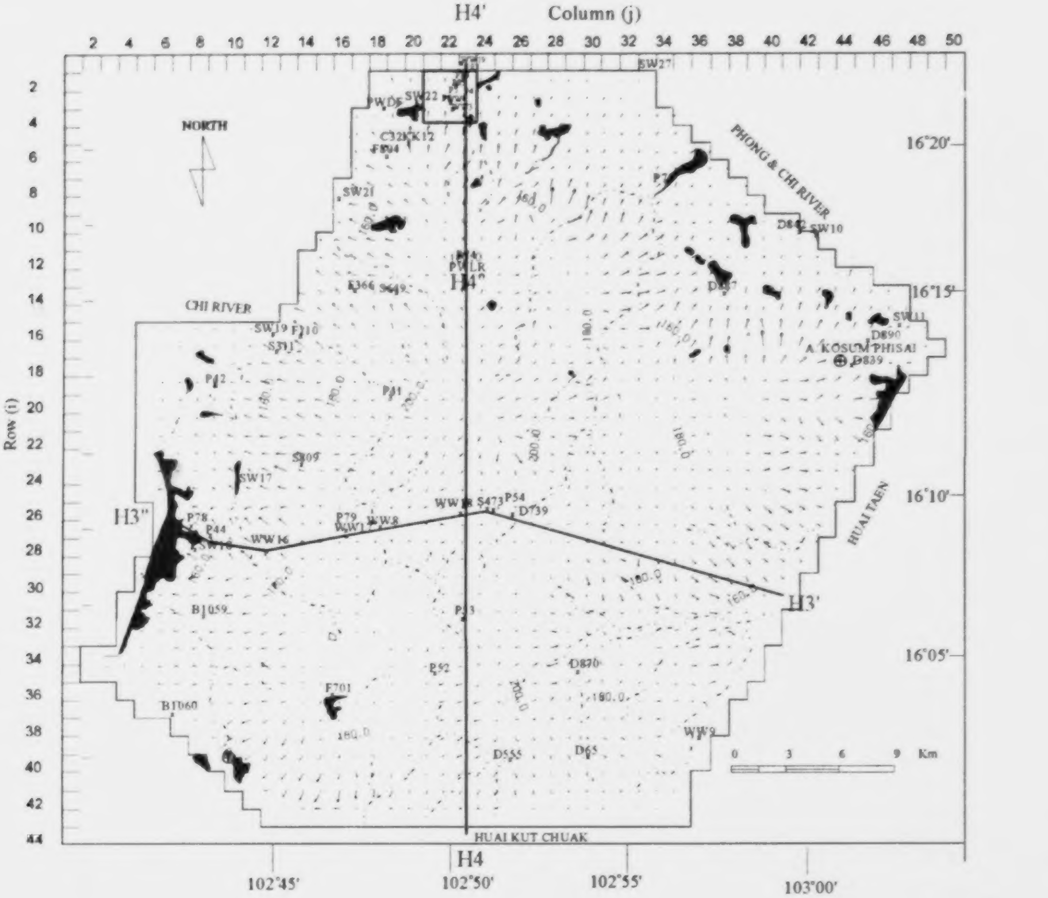
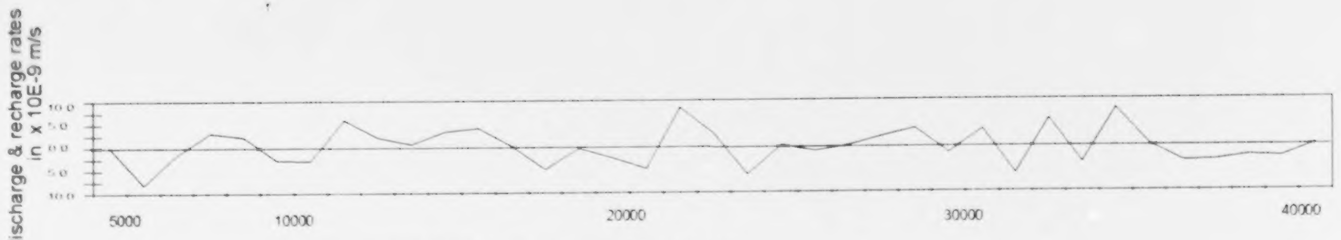

H4'
Column (j)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Row (i)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
NORTH
CHI RIVER
PHONG & CHI RIVER
HUAI TAEN
HUAI KUT CHUAK
A. KOSUM PHISAI
H3"
H3'
H4"
H4
SW22
SW27
SW21
SW19
SW17
SW10
SW11
WW8
WW16
WW9
P78
P44
P54
D739
D870
D555
D65
D890
D839
F701
B1059
B1060
S473
180.0
200.0
0 3 6 9 Km
16°20'
16°15'
16°10'
16°05'
102°45'
102°50'
102°55'
103°00'

Figure 6.20b Distribution of simulated heads and vectors of simulated horizontal groundwater flux for model layer 10 of Hin Tank Hydrogeologic Province

- - .	Stream	$4.0\text{x}10^{-7}$ ⟵	m/s
▬	Lake or reservoir	180	Equipotential line of simulated hydraulic heads in m amsl
H3"——H3'	Line of hydrogeological profile	⬠	Modeled boundary
⊕	Amphoe or district	☐	Ban Nong Khai Nun
WW4 .	Water wells		
P1 & SW22	Piezometers and surface water		



Recharge and discharge profile along H3"-H3'

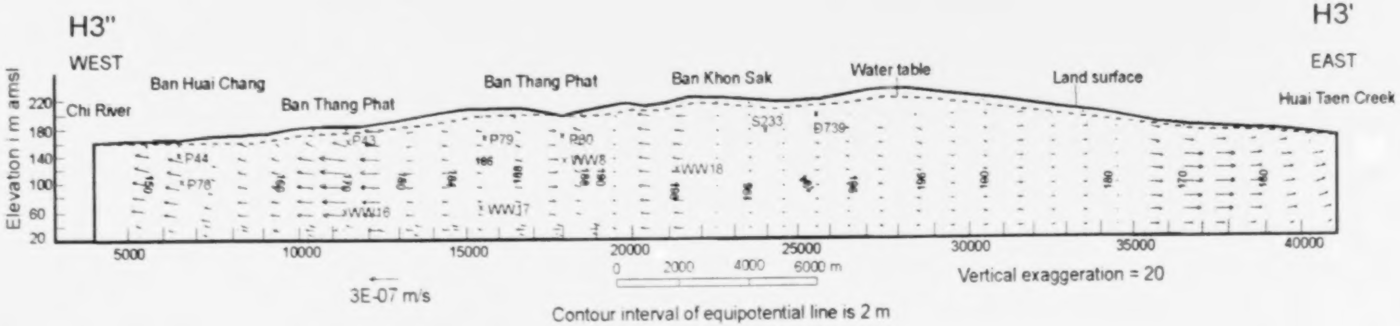
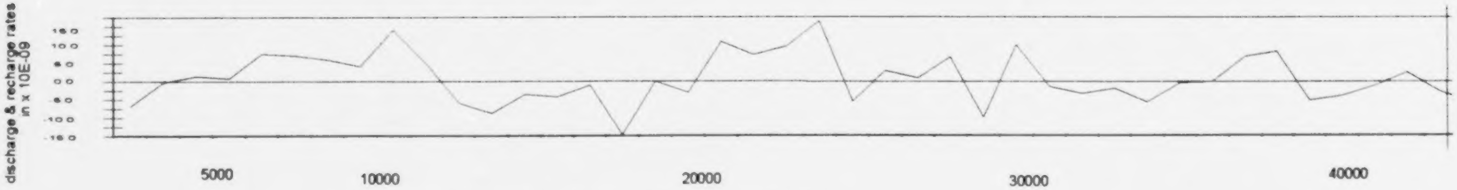
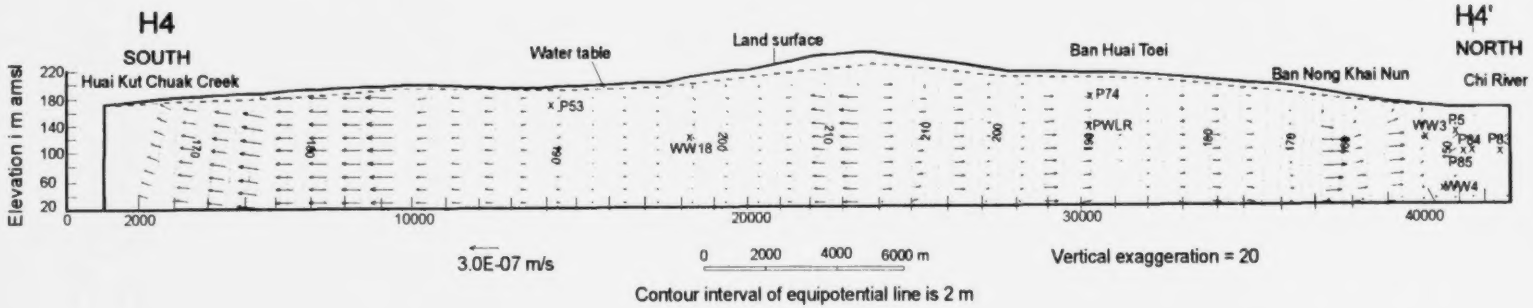

H3"
WEST
H3'
EAST
Elevation i m amsl
220
180
140
100
60
20
Chi River
Ban Huai Chang
Ban Thang Phat
Ban Thang Phat
Ban Khon Sak
Water table
Land surface
Huai Taen Creek
P44
P78
P43
WW16
P79
WW17
R80
WW8
WW18
S233
D739
150
160
170
180
184
186
188
180
170
160
5000
10000
15000
20000
25000
30000
35000
40000
0
2000
4000
6000 m
3E-07 m/s
Vertical exaggeration = 20
Contour interval of equipotential line is 2 m

Figure 6.21a Steady state simulation of hydraulic heads and fluxes along H3" - H3'



Recharge and discharge profile along H4-H4'



H4
SOUTH
Huai Kut Chuak Creek
Water table
Land surface
Ban Huai Toei
Ban Nong Khai Nun
H4'
NORTH
Chi River
x P53
WW18
x P74
xPWLR
WW3
P5
P84
P83
P85
WW4
170
180
190
200
210
210
200
190
180
170
160
Elevation i m amsl
220
180
140
100
60
20
0
2000
10000
20000
30000
40000
3.0E-07 m/s
0
2000
4000
6000 m
Vertical exaggeration = 20
Contour interval of equipotential line is 2 m

Figure 6.21b Steady state simulation of hydraulic heads and fluxes along H4 - H4'

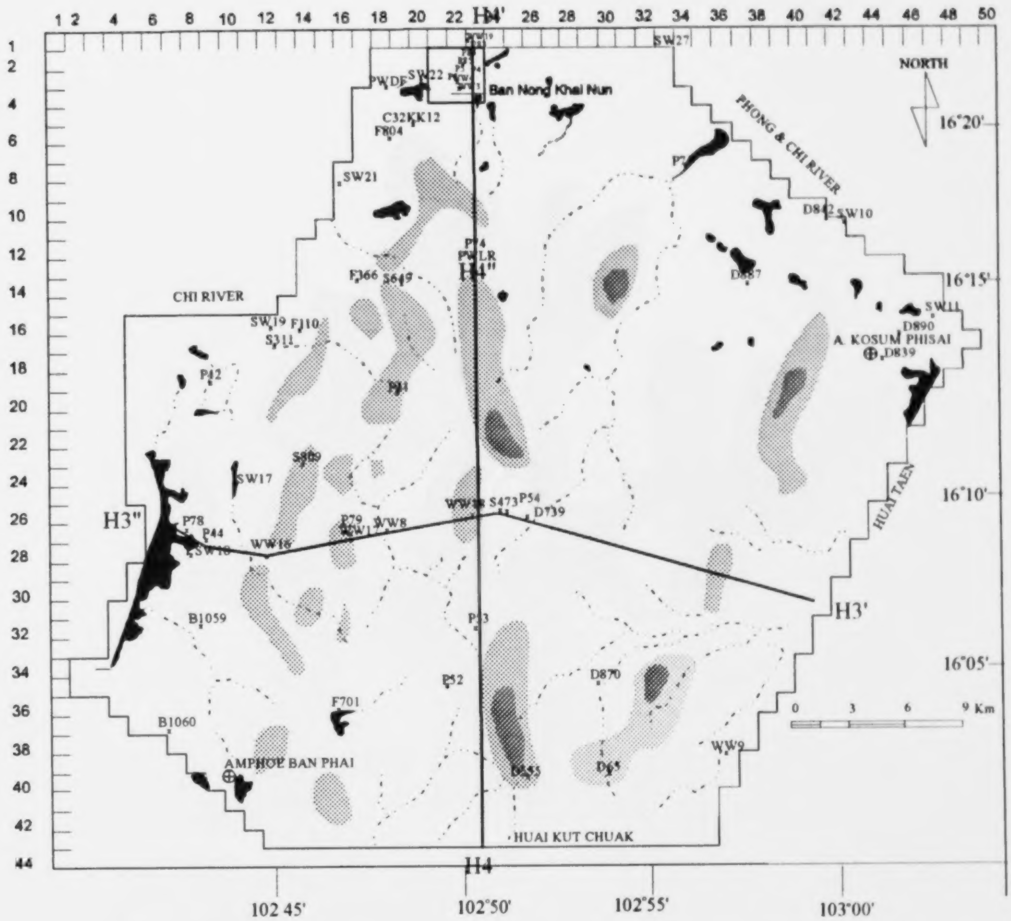

H4'
H4"
H4
H3"
H3'
Ban Nong Khai Nun
NORTH
PHONG & CHI RIVER
CHI RIVER
HUAI TAEN
A. KOSUM PHISAI
AMPHOE BAN PHAI
HUAI KUT CHUAK
16°20'
16°15'
16°10'
16°05'
102 45'
102°50'
102°55'
103°00'
0
3
6
9 Km
SW22
PWDF
C32KK12
F804
SW21
SW27
P7
D842
SW10
D887
SW11
D890
D839
P14
PWLR
F366
S649
SW19
FJ10
S311
P42
P31
S809
SW17
WW18
S473
P54
D739
P78
P44
SW18
WW16
P79
WW1
WW8
B1059
P23
P52
D870
F701
B1060
WW9
D555
D65

Figure 6.22 Distribution of calculated recharge rates by the model simulation for Hin Tank Hydrogeologic Province

Stream

Lake or reservoir

H3"—— H3' Line of hydrogeological profile

⊕ Amphoe or district

WW4 Water wells

P1 & SW22 Piezometers and surface water

Recharge rate in m/s (E-09)

	>0.00 - 2.00
▨	2.00 - 5.00
▩	5.00 - 10.00

Model boundary

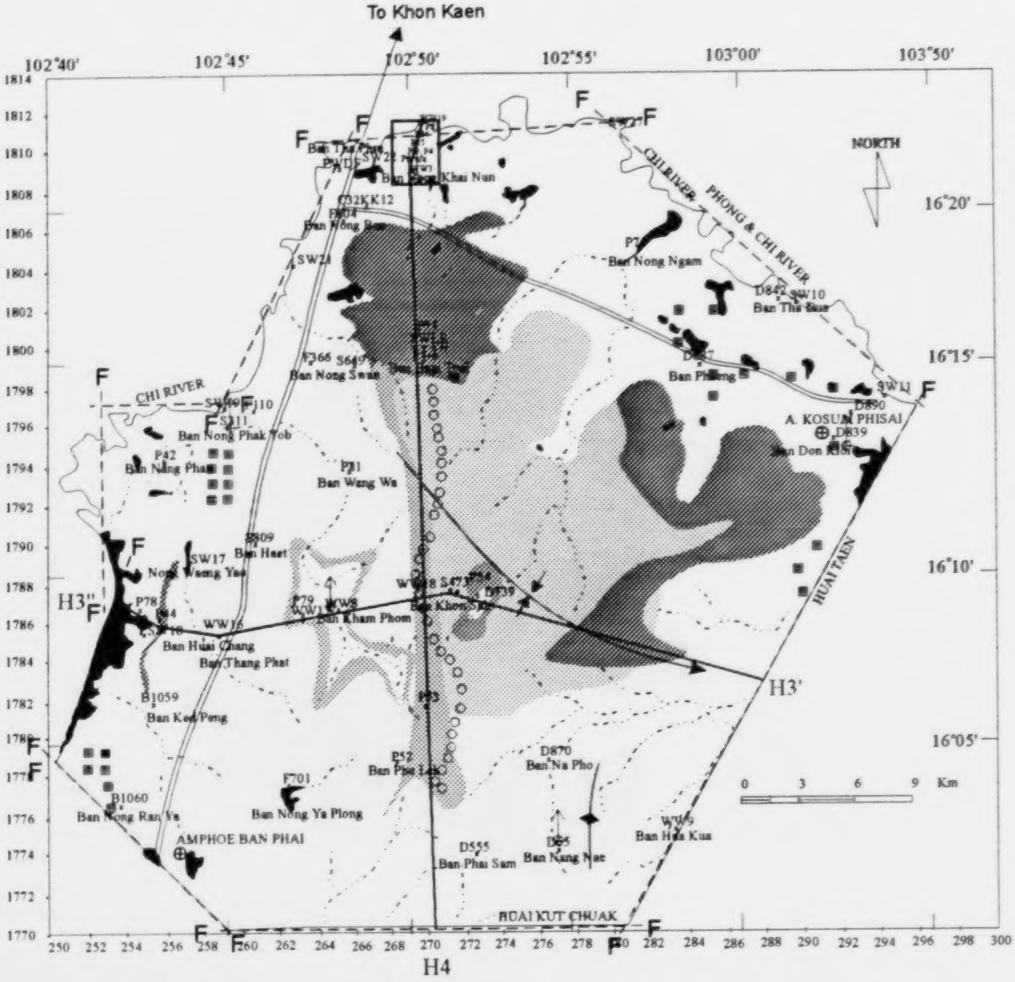

To Khon Kaen
102°40'
102°45'
102°50'
102°55'
103°00'
103°50'
16°20'
16°15'
16°10'
16°05'
NORTH
CHI RIVER
PHONG & CHI RIVER
HUAI TAEN
HUAI KUT CHUAK
Ban Khai Nun
Ban Nong Ngam
Ban Tha Sua
Ban Phaeng
A. KOSUM PHISAI
Ban Don Khong
Ban Nong Swan
Ban Nong Phak Yob
Ban Nong Phai
Ban Wang Wa
Ban Haet
Nong Waeng Yao
Ban Kham Phom
Ban Khon Kaen
Ban Huai Chang
Ban Thang Phat
Ban Ked Peng
Ban Pho Lek
Ban Na Pho
Ban Nong Ran Ya
AMPHOE BAN PHAI
Ban Nong Ya Plong
Ban Phai Sam
Ban Nang Nae
Ban Hua Kua
H3"
H3'
H4
F
0 3 6 9 Km
1814
1812
1810
1808
1806
1804
1802
1800
1798
1796
1794
1792
1790
1788
1786
1784
1782
1780
1778
1776
1774
1772
1770
250
252
254
256
258
260
262
264
266
268
270
272
274
276
278
280
282
284
286
288
290
292
294
296
298
300

Figure 6.23 Distribution of recharge rates estimated by water level fluctuation in Hin Tank Hydrogeologic Province

Stream
Lake or reservoir
H3"——H3' Line of hydrogeological profile
⊕ Amphoe or district
Road and highway
WW4 Water wells
P1 & SW22 Piezometers and surface water
F- - - -F Fault
Syncline axis, plunge
Anticline axis
■ Area of salt precipitate
Flowing well
ooooo Surface and groundwater divide

Recharge rate in m/s (E-09)

>0.00 - 2.00
▒ 2.00 - 5.00
▒ 5.00 - 10.00
▓ 10.00 - 20.00
Hydrogeologic province boundary

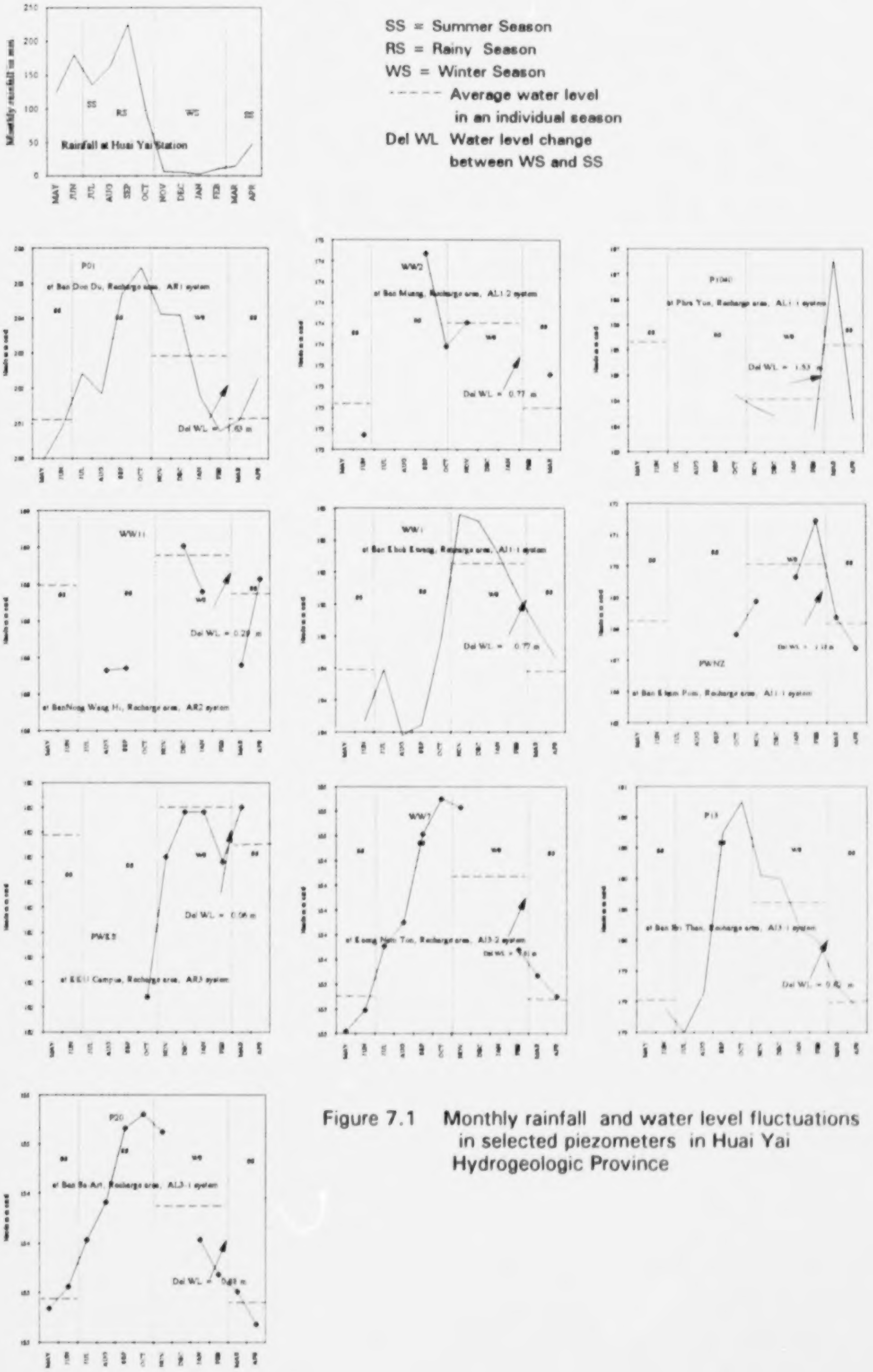


Figure 7.1 Monthly rainfall and water level fluctuations in selected piezometers in Huai Yai Hydrogeologic Province

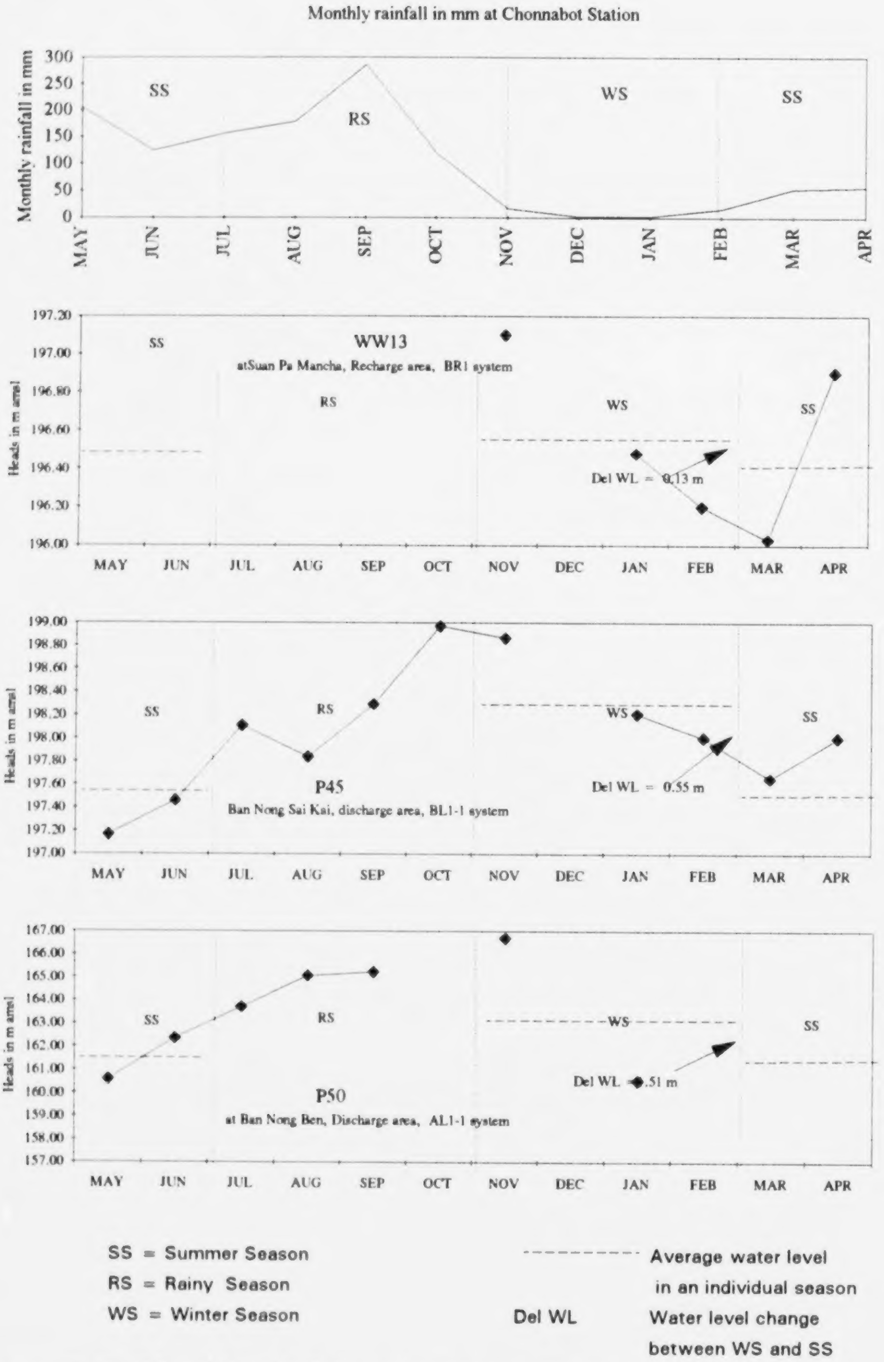


Figure 7. 2 Monthly rainfall and water level fluctuations in selected piezometers in Chonnabot Hydrogeologic Province

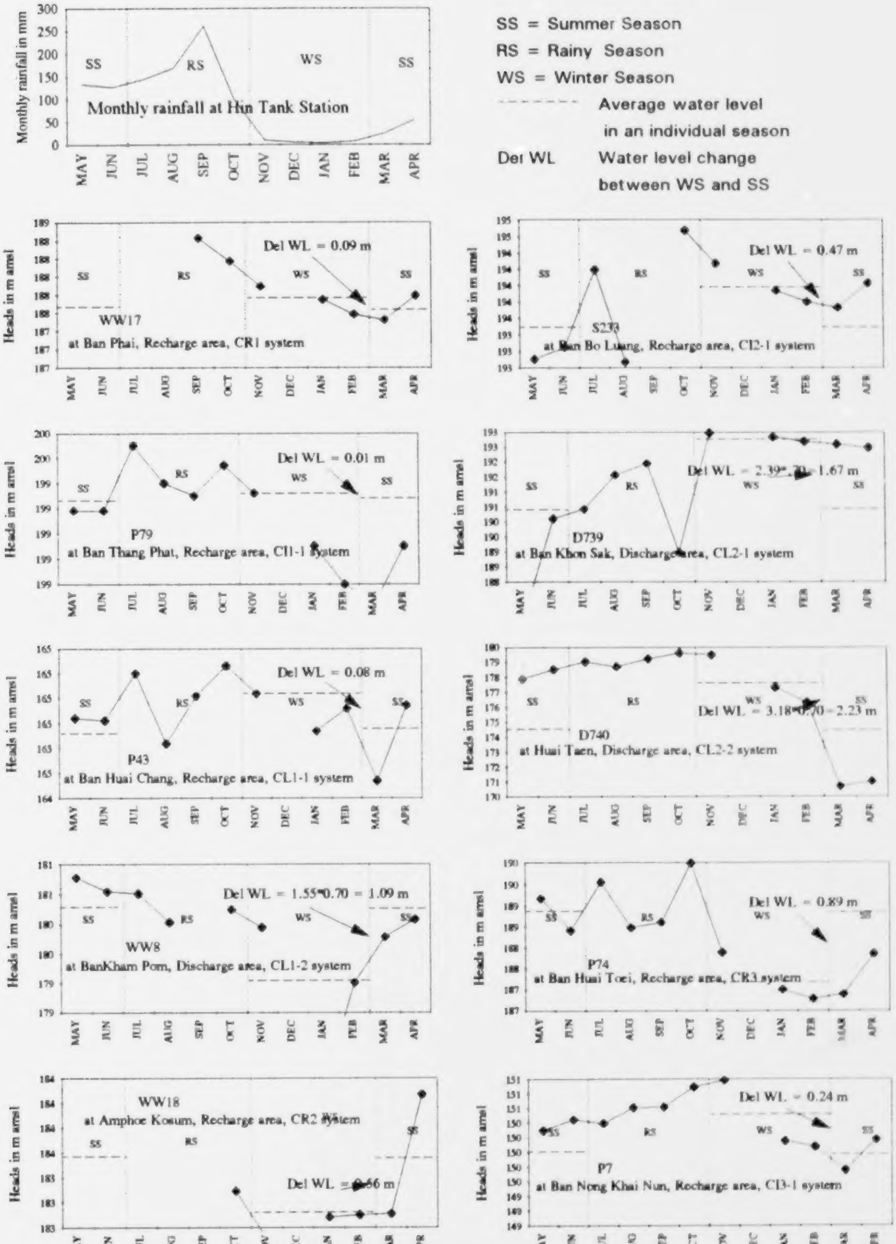


Figure 7.3 Monthly rainfall andwater level fluctuation fluctuation in selected piezometers in Hin Tank Hydrogeologic Province

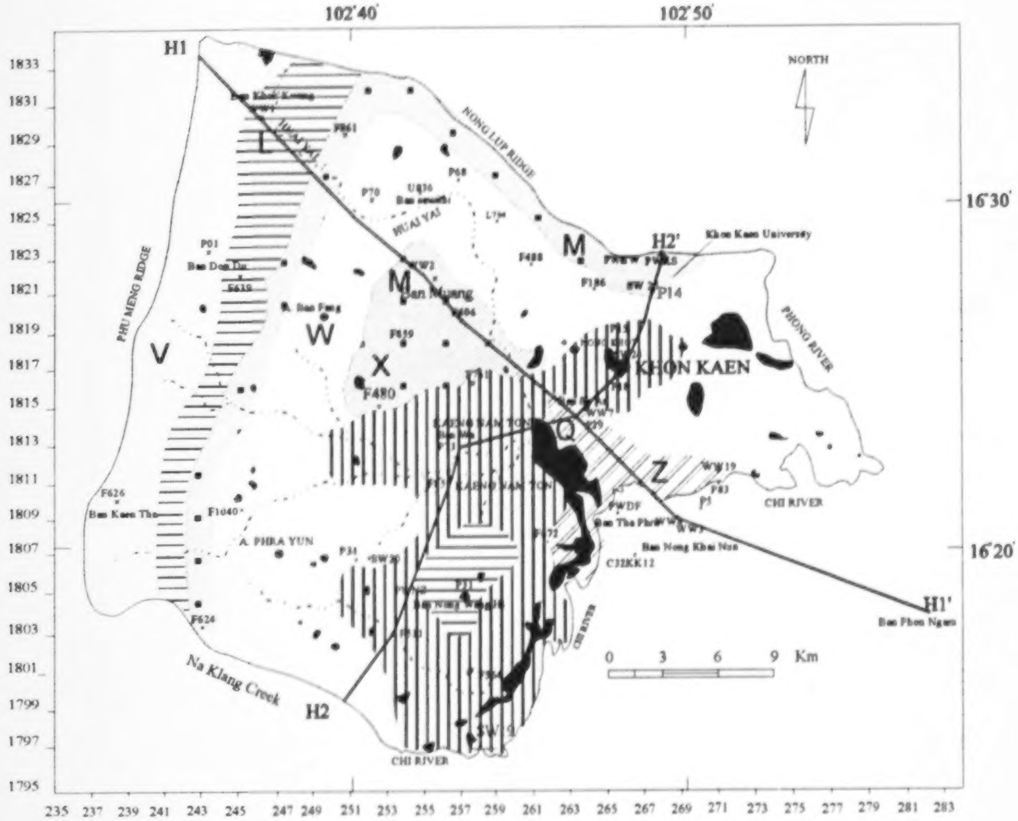

102°40'
102°50'
16°30'
16°20'
NORTH
H1
H1'
H2
H2'
V
L
W
M
X
Q
Z
KHON KAEN
Khon Kaen University
NONG LUP RIDGE
PHU MENG RIDGE
PHONG RIVER
CHI RIVER
Na Klang Creek
HUAI YAI
Ban Muang
A. PHRA YUN
KAENG NAN TON
Ban Phon Ngam
Ban Kaen Tha
Ban Don Du
Ban Nong Khai Nun
Ban Tha Phra
F480
F624
F626
F1040
P14
P01
WW19
SW 9
C32KK12
0 3 6 9 Km
1833
1831
1829
1827
1825
1823
1821
1819
1817
1815
1813
1811
1809
1807
1805
1803
1801
1799
1797
1795
235 237 239 241 243 245 247 249 251 253 255 257 259 261 263 265 267 269 271 273 275 277 279 281 283

Figure 7.4 Groundwater probability map of Huai Yai Hydrogeologic Province

┄	Stream
●	Lake or reservoir
H1____H1'	Line of hydrogeological profile
⊕	Amphoe or district
WW1	Water wells
P20 & SW22	Piezometers and surface water
⬠	Hydrogeologic province boundary

Average expected yield of wells (l/s)

Estimated from pump tests	Estimated from flow regime, lithology etc.	
K	V	0.01-0.50 l/s
L	W	0.50-1.00 l/s
M	X	1.00-5.00 l/s
N	Y	5.00-10.00 l/s
Q	Z	>10.00 l/s

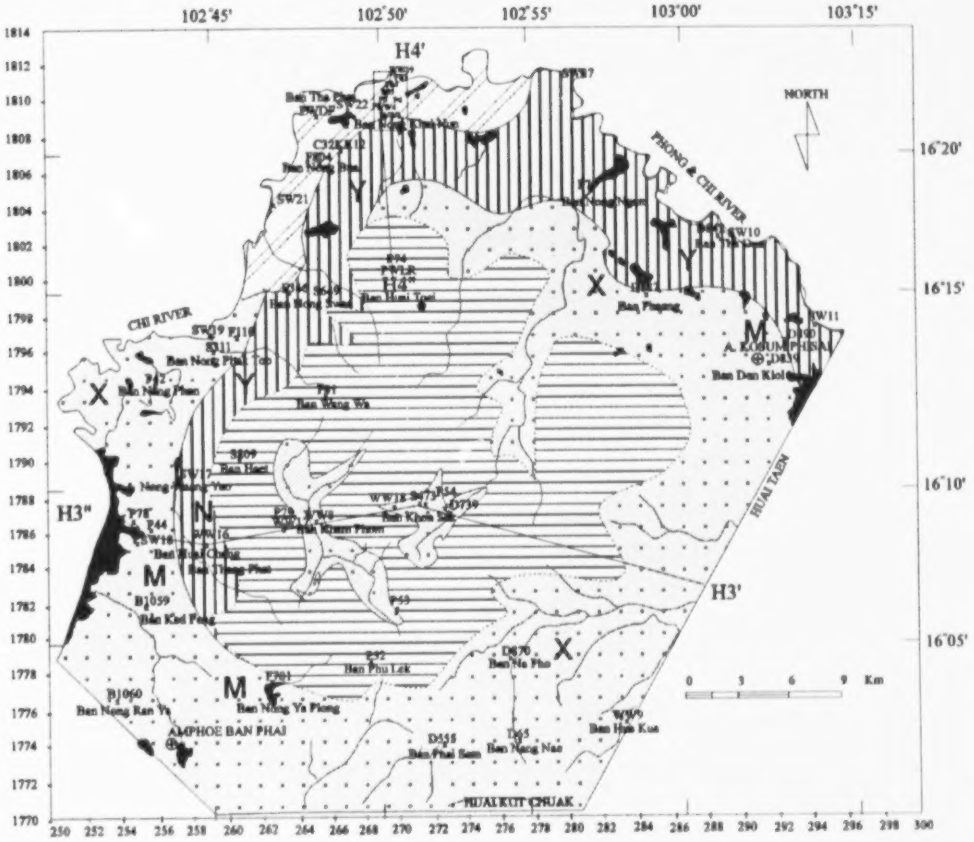

102°45'
102°50'
102°55'
103°00'
103°15'
16°20'
16°15'
16°10'
16°05'
NORTH
H4'
H3"
H3'
X
M
N
CHI RIVER
PHONG & CHI RIVER
HUAI TAEN
HUAI KUT CHUAK
AMPHOE BAN PHAI
A. KOSUMPHISAI
Ban Phu Lek
Ban Na Pho
Ban Nong Ya Plong
Ban Nong Ran Ya
Ban Kud Fong
Ban Phai Sam
Ban Nong Nao
Ban Pla Kua
Ban Dan Klok
Ban Phang
Ban Wang Wa
Ban Haet
SW21
SW10
SW11
WW18
0 3 6 9 Km
1814
1770
250
300

Figure 7.5 Groundwater probability map of Hin Tank Hydrogeologic Province

Stream

Lake or reservoir

H3"___ H3' Line of hydrogeological profile

⊕ Amphoe or district

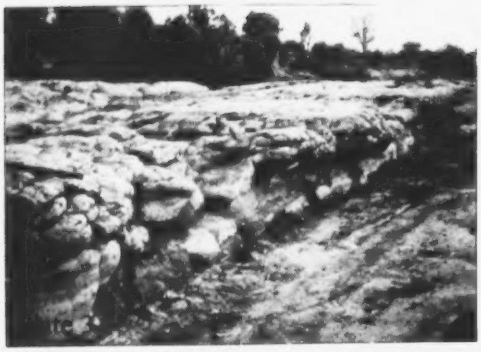
WW4 Water wells

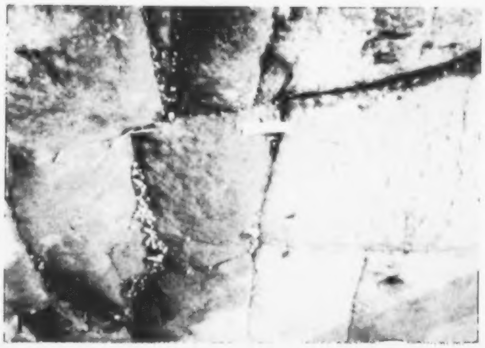
P1 & SW21 Piezometers and surface water

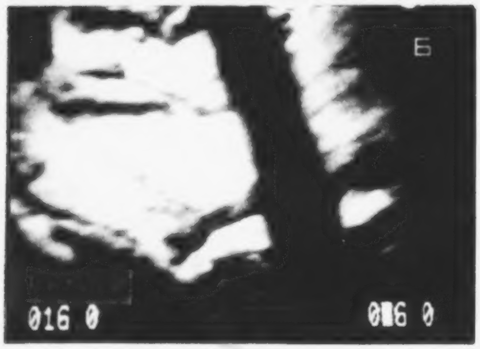
Hydrogeologic province boundary

Average expected yield of wells (l/s)

Estimated from pump tests	Estimated from flow regime, lithology etc.	
K	V	0.01-0.50 l/s
L	W	0.50-1.00 l/s
M	X	1.00-5.00 l/s
N	Y	5.00-10.00 l/s
Q	Z	>10.00 l/s







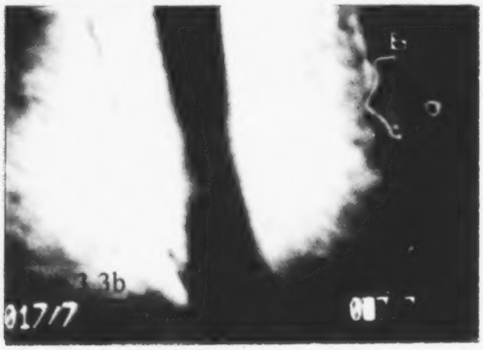


Plate 3.1 Fault breccia in Phu Tok Formation along the Chi River at Ban Nong Buo De Me (12 km South of the town of Khon Kaen)
Plate 3.2 Slip of fractures in Phu Tok Formmation along the Chi River
Plate 3.3.Televiewer log of well P1 at Ban Nong Khai Nun
  a) at 16 m deep showing horizontal fractures
  b) at 17.7 deep showing vertical fractures
  A dark strip is the camera arm
Plate 3.4 Flowing well (P3) and soap holes at Ban Nong Khai Nun paddy field
Plate 3.5 Measurement of flowing well (P4) at Ban Nong Khai Nun

Plate 3.

Plate

Plate 3.8

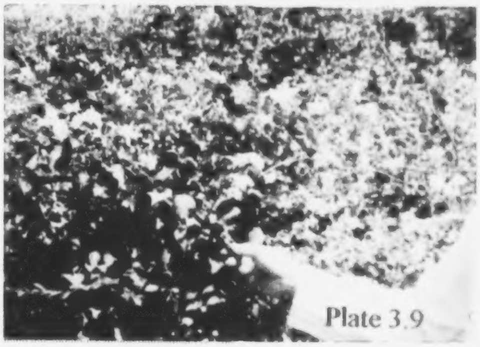


Plate 3.9

Plate 3.10

Plate 3.11

Plate 3.6 Soap holes and salt tolerant plant (*Fimbristylis hookeriana*, Yar Hua Bo) at the west of Ban Nong Khai Nun, Khon Kaen

Plate 3.7 Soap holes and salt tolerant plant (*Fimbristylis hookeriana*, Yar Hua Bo) at the east of Ban Nong Khai Nun, Khon Kaen

Plate 3.8. Salt crust and salt telerant plant at Ban Sa-Art, Khon Kaen

Plate 3.9 *Azima sarmentosa* (Nam Phong Do) is a common halophyte growing in the discharge area at higjly salinised soils

Plate 3.10 *Maytenus mekong gensis* (Nam Daeng) commonly found in the highly salinised soils

Plate 3.11 Community of salt tolerant plants
Gisekia pharmacoides (Pak Bia Daeng), reddish brown
Synostemon bacciformis (Soy Nok Kao), green
Massia triseta (Yar Hua Kai), brown

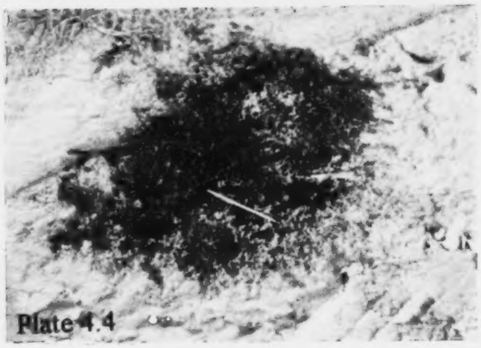


Plate 4.1 Salt mounds at Ban Sa-Art, Khon Kaen
Plate 4.2 Salt harvesting at Ban Sa-Art, Khon Kaen
Plate 4.3 *Azima sarmentosa* (Nam Phong Do) at Ban Sri Than, Khon Kaen University
Plate 4.4 *Gisekia pharmacoides* (Pak Bia Daeng) salt tolerant plant at Ban Nong Lup
Plate 4.5 *Meytenus mekong gensis* (Nam Daeng) commonly grows in highly salinised soils
Plate 4.6 *Plucea indica* (Khlue) commonly grows in lowlands and near salty ponds and reservoirs, at Ban Sri Than, Khon Kaen University

Plate 4.7 Synostemon bacciformis (Soy Nok Kao or Ma Fai Doen Ha) is a common halophyte growing in the discharge area at Ban Nong Lup, Khon Kaen

Plate 4.8 Massia triseta (Yar Hua Kai) commonly grows in highly salinised soils with salt other salt tolerant plant community at ban Nong Lup

Plate 6.1 Vertical fractures in sandstones and siltstones of Phu Tok Formation at Phalan Hin Keang, Hin Tank Hydrogeologic Province University

Plate 6.2 Lineament of trees growing along the vertical fractures in the Phu Tok Formation at Phalan Hin Keang, Hin Tank Hydrogeologic Province

Plate 6.3 Horizontal fracture along bedding plane between pebbly sandstones and shales of the Phu Tok Formation

Appendix 1.1.1 Records of piezometers in the Khon Kaen Drainage Basin

Well No.	Location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing dia.(inches) Length(m) Type	Slotted/Screen Interval(m) Type	Top of Casing (m)	Ground Elev.(m) amsl	Remarks
P1	22m.,E of WW3 Ban Nong Khai Nun Thapra,Amphoe Muang Khon Kaen (691087)	70.5(235) 25/6/88	2.5	4 0-8 PVC	Open Hole	.50	153.51	Drilled by the Project Small top head drive Rotary Rig
P2	150 m. N of WW3 Ban Nong Khai Nun Thapra,Amphoe Muang Khon Kaen (694093)	30(100) 2/6/88	2.5	2 0-8 PVC	Open Hole	.50	152.37	Drilled by the Project Manual set & rotary
P3	200 m. E of P2 Ban Nong Khai Nun Thapra,Amphoe Muang	30(100) 10/6/88	2.5	4 0-8 PVC	Open Hole	.50	150.32	Drilled by the Project Manual set & rotary
P4	286 m. E of P3 Ban Nong Khai Nun Thapra,Amphoe Muang	24.6(82) 8/6/88	2.5	4 0-8 PVC	Open Hole	.50	146.05	Drilled by the Project Manual set & rotary
P5	220 m. N of P4 Ban Nong Khai Nun Thapra,Amphoe Muang	30.9(103) 22/6/88	2.5	4 0-8 PVC	Open Hole	.50	145.41	Drilled by the Project Manual set & rotary
P6	278 m. W of P34 Ban Nong Khai Nun Thapra,Amphoe Muang Khon Kaen (686093)	22(76) 27/6/88	2.5	4 0-8 PVC	Open Hole	.50	152.26	Drilled by the Project Manual set & rotary
P7	300 m. S of WW3 Ban Suan Mon Thapra,Amphoe Muang Khon Kaen (690684)	33.9(130) 30/6/88	3.5	4 0-8 PVC	Open Hole	.50	153.30	Drilled by the Project Small top head drive Rotary Rig
P8	305 m. S of WW3 Ban Nong Khai Nun Amphoe Muang Khon Kaen	12.5(41) 2/7/88	3.5	PVC	Open Hole	.50	153.30	Drilled by the Project Small top head drive Rotary Rig
P11	Near KKU (677230)	54.0(180) 3/7/89	3.5	PVC	PVC	.50	199.28	Drilled by the Project Small top head drive Rotary Rig
P12	N of KKU 4 m.,E of PWKS Amphoe Muang KKU	37.9(125) 4/7/88	3.5	1.5 0-29,31-31.5 PVC	Screen 29-31 PVC	.50	199.28	Drilled by the Project Small top head drive Rotary Rig
P13	Intensive Farm Amphoe Muang KKU (669214)	71.5(235) 15/7/88	3.5	1.5 0-43,45-47 PVC	Screen 43-45 PVC	.50	186.96	Drilled by the Project Small top hard dirve Rotary Rig
P14	5 m.,W of P13 Amphoe Muang KKU (669214)	34.9(130) 15/7/88	3.5	1.5 0-33,35-36 PVC	Screen 33-35 PVC	.50	186.86	Drilled by the Project Small top hard dirve Rotary Rig
P15	Near Srithan Pond Amphoe Muang KKU (666191)	75.8(250) 12/7/88	3.5	1.5 0-72,74-75.5 PVC	Screen 72-74 PVC	.50	160.73	Drilled by the Project Small top hard dirve Rotary Rig
P16	5 m.,S of P15 Amphoe Muang KKU (666191)	34.9(115) 13/7/88	3.5	1.5 0-32,33-33.5 PVC	Screen 32-33 PVC	.50	160.82	Drilled by the Project Small top hard dirve Rotary Rig
P17	Ban Kok,Amphoe Muang Khon Kaen (656196)	63(208) 7/7/88	3.5	1.5 0-59,61-63 PVC	Screen 59-61 PVC	.50	155.55	Drilled by the Project Small top head drive Rotary Rig

Appendix 1.1.1 Records of piezometers in the Khon Kaen Drainage Basin (Cont)

Well No.	Location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing dia.(inches) Length(m) Type	Slotted/Screen Interval(m) Type	Top of Casing (m)	Ground Elev.(m) amsl	Remarks
P18	5m.,W of P17 Amphoe Muang Khon Kaen (656191)	19.7(65) 7/7/88	3.5	1.5 0-18 PVC	Screen 18-19 PVC	.50	155.47	Drilled by the Project Small top head drive Rotary Rig
P19	Ban Non Sa At Amphoe Muang Khon Kaen (632144)	64.2(212) 9/7/88	3.5	1.5 0-57,59-61 PVC	Screen 57-59 PVC	.50	155.79	Drilled by the Project Small top head drive Rotary Rig
P20	5 m.,E of P19,Ban Non-Sa At,Amphoe Muang (432144)	16.7(55) 9/7/88	3.5	1.5 0-14,15-15.5 PVC	Screen 14-15 PVC	.50	155.74	Drilled by the Project Small top head drive Rotary Rig
P21	Ban Muang School Ban Thum,Khon Kaen (547219)	48.5(160) 18/7/88	3.5	1.5 0-45,47-48 PVC	Screen 45-47 PVC	.50	178.20	Drilled by the Project Small top hard dirve Rotary Rig
P22	Ban Muang School Ban Thum,Amphoe Muang (547219)	27.3(85) 19/7/88	6	1.5 0-17,23-26 PVC	Slotted 17-23 PVC	.50	180.52	Drilled by the Project Small top head drive Rotary Rig
P23	30 m.,E of WW1 Ban Khok Kwang Amphoe Muang,Khon Kaen	13.5(45) 5/8/88	3.5	1.5 0-12,13-13.5 PVC	Screen 12-13 PVC	.50	203.20	Drilled by the Project Small top head drive Rotary Rig
P31	Ban Nong Wang Hi Amphoe Pra Yun Khon Kaen (567054)	63.6(210) 27/7/88	3.5	1.5 0-60,62-63.5 PVC	Screen 60-62 PVC	.50	175.00	Drilled by the Project Small top head drive Rotary Rig
P32	Ban Nong Jik Amphoe Pra Yun Khon Kaen (543061)	63.6(210) 28/7/88	3.5	1.5 0-52,60-61.5 PVC	Slotted 52-60 PVC	.50	176.21	Drilled by the Project Small top head drive Rotary Rig
P33	Pra Yun Wittayakan-School,Amphoe Pra Yun Khon Kaen (4980678)	33.3(110) 31/7/88	3.5	1.5 0-32,33-34.5 PVC	Screen 32-33 PVC	.50	181.00	Drilled by the Project Small top head drive Rotary Rig
P41	Ban Wang Wa Amphoe Ban Phai Khon Kaen (657939)	43.9(145) 19/8/88	3.5	3.5	Open Hole	.50	195.00	Drilled by the Project Small top head drive Rotary Rig
P42	Ban Non Phan Chat Khon Kean (562945)	36.4(120) 13/8/88	3.5	1.5 0-27.5 PVC	Slotted 27.5-35.5 PVC	.50	157.00	Drilled by the Project Small top head drive Rotary Rig
P43	Ban Thang Phat Amphoe Ban Phai (586862)	42.4(140) 14/8/88	3.5	1.5 0-33 PVC	Slotted 33-41 PVC	.50	173.15	Drilled by the Project Small top head drive Rotary Rig
P44	Ban Hua Chang Amphoe Ban Phai (552866)	57.6(190) 18/8/88	3.5	1.5 0-46 PVC	Slotted 46-54 PVC	.50	159.08	Drilled by the Project Small top head drive Rotary Rig
P45	Ban Nong Sai Kai Mmphoe Manchakiri (423006)	50(165) 20/8/88	3.5	1.5 0-41 PVC	Slotted 41-49 PVC	.50	204.00	Drilled by the Project Small top head drive Rotary Rig
P46	Wat Suan Pa Mancha Amphoe Manchakiri (439924)	50(165) 23/8/88	3.5	4 0-12 PVC	Open hole	.50	205.89	Drilled by the Project Small top head drive Rotary Rig
P48	Ban Nong Hua Chang Amphoe Manchakiri (459864)	50(165) 4/9/88	3.5	1.5 0-12 PVC	Open hole	.50	170.00	Drilled by the Project Small top head drive Rotary Rig
P49	20 m. N of P48 Ban Na Chan Amphoe Manchakiri	25.8(85) 7/9/88	3.5	1.5 0-21 PVC	Slotted 21-24 PVC	.50	170.00	Drilled by the Project Small top head drive Rotary Rig

Appendix 1.1.1 Records of piezometers in the Khon Kaen Drainage Basin (Cont)

Well No.	Location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing dia.(inches) Length(m) Type	Slotted/Screen Interval(m) Type	Top of Casing (m)	Ground Elev.(m) amsl	Remarks
P50	Ban Nong Pan Amphoe Manchakiri (494895)	63.6(210) 10/9/88	3.5	1.5 0-54 PVC	Slotted 54-62 PVC	.50	158.15	Drilled by the Project Small top head drive Rotary Rig
P52	Ban Phu Lek Amphoe Ban Phai (689790)	60.6(200) 1/11/88	3.5	1.5 0-51 PVC	Slotted 51-59 PVC	.50	201.00	Drilled by the Project Small top head drive Rotary Rig
P53	Ban Phu Lek Amphoe Ban Phai (691823)	36.4(120) 24/10/88	3.5	1.5 0-27 PVC	Slotted 27-35 PVC	.50	201.00	Drilled by the Project Small top head drive Rotary Rig
P54	Ban Khon Sak Amphoe Ban Phai (709881)	60.6(200) 23/11/88	3.5	1.5 0-51 PVC	Slotted 51-59 PVC	.50	195.77	Drilled by the Project Small top head drive Rotary Rig
P58	Ban Nong Son Amphoe Chiang yun (002078)	60.6(200) 3/11/88	3.5	1.5 0-51 PVC	Slotted 51-59 PVC	.50	152.00	Drilled by the Project Small top head drive Rotary Rig
P59	Ban Bung sawang Amphoe Muang (818163)	62.1(205) 12/11/88	3.5	1.5 0-52 PVC	Slotted 52-60 PVC	.50	181.00	Drilled by the Project Small top head drive Rotary Rig
P60	Ban Nong Waeng Amphoe Chiang yun (036174)	60.6(200) 7/11/88	3.5	1.5 0-52 PVC	Slotted 52-58 PVC	.50	167.00	Drilled by the Project Small top head drive Rotary Rig
P61	Ban Kham Mon Pla Huai Mek (054253)	56.1(185) 10/11/88	3.5	1.5 0-47 PVC	Slotted 47-55 PVC	.50	182.00	Drilled by the Project Small top head drive Rotary Rig
P63	Ban Wang Phon School,Kranuan Khon Kaen (009405)		3.5	PVC	PVC	.50	190.00	Drilled by the Project Small top head drive Rotary Rig
P66	Ban Pa Chat Amphoe Nam Phong (797380)	57.6(190) 14/11/88	3.5	1.5 0-48 PVC	Slotted 48-56 PVC	.50	182.00	Drilled by the Project Small top head drive Rotary Rig
P67	Huai Hai Station Khon Kaen (703337)	62.1(205) 15/11/88	3.5	1.5 0-53 PVC	Slotted 53-61 PVC	.50	180.00	Drilled by the Project Small top head drive Rotary Rig
P68	Ban Ngew Sawathi,Amphoe Muang (563272)	51.5(170) 25/10/88	3.5	1.5 0-37 PVC	Slotted 37-50 PVC	.50	173.00	Drilled by the Project Small top head drive Rotary Rig
P70	Ban Nong Takai Sawathi,Amphoe Muang (551248)	51.5(170) 22/10/88	3.5	1.5 0-28 PVC	Slotted 28-40 PVC	.50	184.00	Drilled by the Project Small top head drive Rotary Rig
P73	Ban Wa Amphoe Muang (568124)	51.5(170) 21/10/88	3.5	1.5 0-38 PVC	Slotted 38-50 PVC	.50	157.31	Drilled by the Project Small top head drive Rotary Rig
P74	Ban Huai Toei Rand Reform Develoment Area (693001)	63.3(210) 19/10/88	3.5	1.5 0-26,32-48 PVC	Slotted 26-32,48-56 PVC	.50	200.00	Drilled by the Project Small top head drive Rotary Rig
P75A	Ban Phon Ngam Amphoe Kosum Phisi Mahasarakham (828044)	51.5(170) 4/11/88	3.5	1.5 0-44 PVC	Slotted 44-60 PVC	.50	152.67	Drilled by the Project Small top head drive Rotary Rig
P75	Ban Phon Ngam 6m. NW of P75A Amphoe Kosum Phisai Mahasarakham (828044)	25.8(85) 3/11/88	3.5	1.5 0-18 PVC	Slotted 18-24 PVC	.50	152.63	Drilled by the Project Small top head drive Rotary Rig
P76	Ban Don Bom Amphoe Muang Khon Kaen	61(200) 26/4/89	3.5	1.5 0-52.5 PVC	Screen 52.5-53.5 PVC	.50	145.60	Drilled by the Project Small top head drive Rotary Rig

Appendix 1.1.1 Records of piezometers in the Khon Kaen Drainage Basin (Cont)

Well No.	Location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing dia.(inches) Length(m) Type	Slotted/Screen Interval(m) Type	Top of Casing (m)	Ground Elev.(m) amsl	Remarks
	(689083)							
P77	Ban Chi Khok Kho Amphoe Ban Phai Khon Kaen (507890)	57.0(190) 23/4/89	3.5	1.5 0-52.5 PVC	Screen 52.5-53.5 PVC	.50	157.75	Drilled by the Project Small top head drive Rotary Rig
P78	Ban Hua Chang Amphoe Ban Phai Khon Kaen (557862)	60(200) 21/4/89	3.5	1.5 0-51 PVC	Screen 58.5-59.5 PVC	.50	157.40	Drilled by the Project Small top head drive Rotary Rig
P79	Ban Kham Pom Amphoe Ban Phai Khon Kaen (630869)	60(200) 20/4/89	3.5	1.5 0.58 PVC	Screen 54.5-55.5 PVC	.50	195.55	Drilled by the Project Small top head drive Rotary Rig
P80	Ban Kham Pom School Amphoe Ban Phai Khon Kaen (551248)	61(200.08) 12/10/88	3.5	1.5 0-58 PVC	Screen 59-60 PVC	.50	180.57	Drilled by the Project Small top head drive Rotary Rig
P81	Wat Ban Don Bom Amphoe Muang Khon Kaen (705114)	60(200) 17/4/89	3.5	1.5 0-58 PVC	Screen 52.5-53.5 PVC	.50	145.46	Drilled by the Project Small top head drive Rotary Rig
P82	Wat Ban Don Bom Amphoe Muang Khon Kaen (705114)	60(200) 19/4/89	3.5	1.5 0-53 PVC	Screen 53-54 PVC	.50	145.50	Drilled by the Project Small top head drive Rotary Rig
P83	Ban Don Bom Amphoe Muang Khon Kaen (705114)	60(200) 8/4/89	3.5	1.5 0-58 PVC	Screen 46-47 PVC	.50	141.90	Drilled by the Project Small top head drive Rotary Rig
P84	Wat Nong Khai Nun Amphoe Muang Khon Kaen (689089)	60(200) 9/4/89	3.5	1.5 0-58 PVC	Screen 55-56 PVC	.50	143.92	Drilled by the Project Small top head drive Rotary Rig
	Ban Nong Khai Nun	61(200)		1.5	Screen			Drilled by the Project

Appendix 1.1.2 Records of pumped wells drilled by GREP and Private organizations

Well No	location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing Dia.(") Length(m) Type	Slotted/Screen Interval(m) Type	Top of casing agl (m)	Ground elev. m. amsl	Geologic FM.	Remarks
Well No	location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing Dia.(") Length(m) Type	Slotted/Screen Interval(m) Type	Top of casing agl (m)	Ground elev. m. amsl	Geologic FM.	Remarks
WW1	Ban Khok Kwang Amphoe Ban Fang Khon Kaen (472291)	47.2(155) 19/07/88	10	6 0-28.9,9-40.9 API	Slotted 28.9-34.9,40.9-46 ASTM	0.15	203.89	Phu Phan	Drilled by DMR Rotary Rig
WW2	Ban Muang School Amphoe Muang Khon Kaen (547219)	48.8(160) 17/07/88	10	6 0-31.9 API	Slotted 31.9-41.9 ASTM	0.15	180.52	Mahasarakham	Drilled by DMR Rotary Rig
WW3	Ban Nong Khai Nun Tha Pra, Amphoe Muan Khon Kaen (691087)	48.5(160) 5/07/88	10	6 0-31.9 API	Slotted 31.9-41.9 ASTM	0.15	153.65	Phu Tok	Drilled by DMR Rotary Rig
WW4	Ban Nong Khai Nun Tha Pra, Amphoe Muan Khon Kaen (694093)	131.1(430) 24/2/80	12 0-30.48 m. 6 30.48-131.1 m.	8 42.68 ASTM	Open Hole	0.15	152.19		Drilled by DMR Rotary Rig
WW7	Ban Non Sa-Art Amphoe Muang Khon Kaen (632144)	120.42(397.3 9/05/89	12 0-36.58 m. 6 36.58-119.7 m.	8 0-36.58 ASTM	Open Hole	1.31	155.91		Drilled by DMR Rotary Rig
WW8	Ban Kham Pom, Amphoe Ban Phai Khon Kaen (665233)	71.1(235) 17/12/88	10	5 0-18.2,24.2-48.5 API	Slotted 18.2-24.2,48.5-60 ASTM	0.15	180.81	Phu Tok	Drilled by DMR Rotary Rig
WW9	Ban Hua Khua, Amphoe Borabu Mahasarakham (826756)	90.9(200) 24/12/88	10	5 0-12.1 API	Open Hole	0.15	180.00	Phu Tok	Drilled by DMR Rotary Rig
WW10	Ban Nong Kheen, Amphoe Borabu Mahasarakham (893827)	60.6(200) 16/12/88	10	5 0-12.1 API	Open Hole	0.15	160.78	Phu Tok	Drilled by DMR Rotary Rig
WW11	Ban Nong Chik Amphoe Pra Yuen Khon Kaen (543061)	94.51(310) 14/08/89	6	5 0-30.48 ASTM	Open Hole	0.22	176.61		Drilled by DMR Rotary Rig
WW13	Ban Huai Hin Keang Amphoe Mancha Khiri Khon Kaen (434926)	137.2(450) 14/08/89	6	5 0-80 ASTM	Open Hole		214.00		Drilled by DMR Rotary Rig
WW16	Ban Tang Pad Amphoe Ban Phai Khon Kaen (594862)	126.5(415) 8/02/89	12 0-42.68 m. 6 42.68-126 m.	8 0-30.48 ASTM	Slotted 30.48-36.58 Open Hole 42.68-126.5	0.03	173.02		Drilled by DMR Rotary Rig
WW17	Ban Kham Pom Amphoe Ban Phai Khon Kaen (434926)	149.4(490) 4/09/89	6	5 0-80 ASTM	Open Hole	0.14	196.08		Drilled by DMR Rotary Rig
WW18	Ban Khon Sak Amphoe Ban Phai Khon Kaen (688878)	152.4(500) 11/09/89	6	5 0-80 ASTM	Open Hole	0.22	216.21		Drilled by DMR Rotary Rig
WW19	Wat Don Bom Muang Kao, A.Muang,KK (705114)	121.9(400) 12/07/89	6	5 30.48 ASTM	Open Hole	0.45	145.35		Drilled by DMR Rotary Rig
S913	Tha Phra Nao Anphoe Muang Khon Kaen (652088)	91.46 15/02/89	12	8 ASTM	Slotted & Screen 54.88-60.98 67.07-73.17 79.27-85.36	0.12			Drilled by DMR Rotary Rig
PWKS	80 m.,N of KKU (676232)	78.6(258) 6/06/88	10	5 0-27,35-59 PVC	Slotted 27-35,59-67 pvc	0.50	199.28	Quaternary gravel and san	Private well Rotary Rig
PWKC	50m.,E of PWKS	36.6(120.0) 1/06/88	10	5 0-26 PVC	Slotted & Screen 26-30,30-34 PVC ,stainless	0.50		Quaternary and sand	Private well Rotary Rig
PWTW	150m. W of PWKS	94.5(310) 15/07/88	10	5 0-64.8,72.8-76.8, 80.8-82.8,86.8-88 (PVC)	Slotted 64.8-72.8,76.8-80 82.8-86.8,88.8-92.8 (PVC)	0.50	196.50	Khok Kruat	Private well Rotary Rig
PWDF	Dye factory Tha Phra,Khon Kaen (656086)	90(300) 10/08/88	10	6 0-69,75-81 API	Slotted 69-75,81-87 ASTM	0.50	158.00	Phu Tok	Private well Percussion Rig
PWLR	Ban Huai Toei Rand Reform Development Area (693001)	105 20/05/89	12	10 0-210 ASTM	Slotted 66-90 Screen 90-102	1.19	201.00		Private well Rotary Rig
PWNZ							176.53		Private well Rotary Rig
PWCF	Chicken Farm Ban Kok Amphoe Muang	42.4(140) 19/11/89							Private well Rotary Rig

Appendix 1.1.3 Records of water wells drilled by the Department of Mineral Resources

Well No.	Location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing Dia.(") Length(m) Type	Slotted/Screen Interval(m) Type	Ground elev. m. above M.S.L.	Remarks
D827	Ban Nong Khu Amphoe Chiang Yuen Mahasarakham (048027)	18.3		4	12.2-18.3	163.00	Drilled by DMR Rig
D945	Ban Nong Mai Tai Amphoe Chiang Yuen Mahasarakham (003143)	21.34		4	15.2-21.3	154.00	Drilled by DMR Rig
D702	Ban Non Muang Amphoe Kosumphisai Mahasarakham (939049)	18.3		4	12.2-18.3	150.00	Drilled by DMR Rig
D605	Ban Saen Amphoe Kantharawichai Mahasarakham (066009)	15.2		4	9.1-15.2	146.00	Drilled by DMR Rig
D756	Ban Kaeng Kosum Amphoe Kosumphisai Mahasarakham (942996)	24.4		4	18.3-24.4	154.00	Drilled by DMR Rig
F641	Ban Non Khong Amphoe Ban Fang Khon Kaen (430149)	33.5		5	27.43-33.53	190.00	Drilled by DMR Rig
F862	Ban Nong I Wang Amphoe Nong Rue Khon Kaen (368123)	60.9		4	48.7-60.9	226.00	Drilled by DMR Rig
F112	Ban Khok Sung Amphoe Ubonratana Khon Kaen (830510)	42.7		6	27.4-39.6	195.00	Drilled by DMR Rig
F586	Ban Nong Kung Soen Amphoe Phu Wiang Khon Kaen (379405)	39.6		5	27.4-39.6	190.00	Drilled by DMR Rig
F822	Ban Khai Nun Amphoe Muang Khon Kaen (375338)	21.3		4	15.2-21.3	183.00	Drilled by DMR Rig
F647	Ban Nong Phu Amphoe Nong Rue Khon Kaen (416332)	42.7		5	36.6-42.7	195.00	Drilled by DMR Rig
F751	Ban Khok Lao Amphoe Nam Phong Khon Kaen (830510)	30.5		4	18.3-24.4	165.00	Drilled by DMR Rig
F766	Wat Ban Nongbuaban Amphoe Nam Phong Khon Kaen (785446)	39.6		4	33.5-39.6	184.00	Drilled by DMR Rig
S509	Ban Kham Kaen Khun Amphoe Nam Phong Khon Kaen 665440	42.7		4	24.4-30.5	173.00	Drilled by DMR Rig
S634	Wat Ban Sakut Amphoe Nam Phong Khon Kaen (609411)	61.0		4	42.7-48.8	182.00	Drilled by DMR Rig
U820	Ban Dong Yen Amphoe Nam Phong Khon Kaen (853371)	21.3		4	18.3-21.3	190.00	Drilled by DMR Rig
F472	Wat Ban Non Ruang Amphoe Muang Khon Kaen (627291)	47.2		5	35-47.2	171.00	Drilled by DMR Rig
F531	Ban Kham Pom Amphoe Pra Yuen Khon Kaen (530026)					168.00	Drilled by DMR Rig
F726	Ban Khok Tha Amphoe Muang Khon kaen (775285)	30.5		7	24.4-30.5	160.00	Drilled by DMR Rig

Appendix 1.1.3 Records of water wells drilled by the Department of Mineral Resources (Cont.)

Well No.	Location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing Dia.(") Length(m) Type	Slotted/Screen Interval(m) Type	Ground elev. m. above M.S.L	Remarks
F776	Ban Na Lo Amphoe Karnuan Khon Kaen (923508)	51.8		4	45.7-51.8	191.00	Drilled by DMR Rig
Y379	Ban Phimun Amphoe Huai Mek Karasin (035460)	24.4		5	17.3-24.4	191.00	Drilled by DMR Rig
S668	Ban Na Fai Amphoe Karnuan Khon Kaen (889450)	50.3		4	42.7-48.8	201.00	Drilled by DMR Rig
S638	Ban Sok Khao Kaeo Amphoe Karnuan Khon Kaen (966360)	54.9		4	24.4-30.5	200.00	Drilled by DMR Rig
S675	Ban Luplao Amphoe Huai Mek Karasin (788322)	33.53		4	12.2-18.3	190.00	Drilled by DMR Rig
Y813	Ban Kham Muat Kaeo Amphoe Huai Mek Karasin (937284)	36.6		5	30.5-36.6	196.00	Drilled by DMR Rig
S672	Ban Nong Buakhanmoon School Amphoe Kranuan Khon Kaen (876255)	42.6		5	18.3-24.4	171.00	Drilled by DMR Rig
U838	Ban Huryrai Amphoe Chonnabot Khon Kaen (403767)	36.6		5	24.4-36.6	166.00	Drilled by DMR Rig
S535	Ban Na Fai Amphoe Chonnabot Khon Kaen (438747)	18.3		4	12.2-18.3	172.00	Drilled by DMR Rig
S659	Ban Chonnabot Suksa School A.Chonnabot Khon Kaen (454801)	48.8		6	18.3-24.4 30.5-36.6	169.00	Drilled by DMR Rig
U831	Ban Kranaun Amphoe Kranuan Khon Kaen (876255)	36.6		4	30.5-36.6	183.00	Drilled by DMR Rig
X231	Ban Nong Chik Amphoe Borabu Mahasarakham (025725)					178.00	Drilled by DMR Rig
F639	Wat Ban Nong Bua Amphoe Fang Khon Kaen (456222)	27.4		5	21.34-27.43	199.00	Drilled by DMR Rig
F459	Ban Daeng Noi Amphoe Muang Khon Kaen (535183)	18.3		5	15.19-18.29	172.00	Drilled by DMR Rig
F761	Wat Ban Lao Kwian Hak Amphoe Muang Khon Kaen (573164)	4.6		4	35.5-42.6	161.00	Drilled by DMR Rig
F480	Ban Khor Amphoe Ban Fang Khon Kaen (526153)	18.3		5	12.19-18.29	175.00	Drilled by DMR Rig
F626	Ban Kaen Thao Amphoe Fang Khon Kaen (383097)	24.33		4	18.29-24.39	220.00	Drilled by DMR Rig
F564	Ban Thon Amphoe Pra Yuen Khon Kaen (583005)	30.4		4	24.3-30.4	160.00	Drilled by DMR Rig
F859	Wat Ban Tao Amphoe Muang Khon Kaen 565113)	18.3		4	12.1-18.29	157.76	Drilled by DMR Rig
F532	Wat Patchim Ban Sawang Amphoe Ban Fang	48.8		6	36.6-48.8	213.00	Drilled by DMR Rig

Appendix 1.1.3 Records of water wells drilled by the Department of Mineral Resources (Cont.)

Well No.	Location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing Dia.(") Length(m) Type	Slotted/Screen Interval(m) Type	Ground elev. m. above M.S.L.	Remarks
	Khon Kaen (579431)						
F861	Ban Hin Khow Amphoe Muang Khon Kaen (505294)	61.0		4	36.6-42.7	195.00	Drilled by DMR Rig
F642	Ban Na Fai Amphoe Ban Fang Khon Kaen (423262)	33.5		5	27.4-33.5	200.00	Drilled by DMR Rig
F672	Ban Nong Hi Amphoe Muang Khon Kaen (623080)	24.4			18.3-24.4	153.00	Drilled by DMR Rig
F488	Ban Nong Lup Amphoe Muang Khon Kaen (606224)	18.3		5	12.2-18.3	170.00	Drilled by DMR Rig
F186	Khon Kaen Airport Amphoe Muang Khon Kaen (642215)	83.6		6	59.4-77.7	190.00	Drilled by DMR Rig
F401	Ban Sa-Art School Amphoe Muang Khon Kaen (634149)	24.4		4	18.3-24.4	155.00	Drilled by DMR Rig
F841	Ban Thadout A.Kosumphisai Mahasarakham (894027)					148.00	Drilled by DMR Rig
F624	Ban Pradu Amphoe Pra Yuen Khon Kaen (429031)	39.6		5	36.58-39.63	200.00	Drilled by DMR Rig
F531	Ban Kham Pom Amphoe Pha Yuen Khon Kaen (530206)					168.00	Drilled by DMR Rig
F1040	Ban Nong Khu Amphoe Pha Yuen Khon Kaen (446095)					193.00	Drilled by DMR Rig
L794	Wat Pa Ban Non Kloi Amphoe Muang Khon Kaen (587253)	30.5		4	24.4-30.5	178.00	Drilled by DMR Rig
U836	Ban Sawathi Amphoe Muang Khon Kaen (545262)	21.3		6	15.2-21.3	180.00	Drilled by DMR Rig
L791	Ban Non Ngiew Amphoe Monchakiri Khon Kaen (498995)	18.2		4	12.1-18.2	171.00	Drilled by DMR Rig
L798	Ban Phon Phek School Amphoe Monchakiri Khon Kaen (375915)	21.3		4	15.2-18.3	183.00	Drilled by DMR Rig
S709	Ban Lum Kha Amphoe Monchakiri Khon Kaen (376815)	54.9		4	36.6-42.7 48.4-54.9	167.00	Drilled by DMR Rig
S715	Ban Non Khun School Amphoe Monchakiri Khon Kaen (403043)	33.5		4	27.4-33.5	227.00	Drilled by DMR Rig
S832	Ban Nong Hai School Amphoe Monchakiri Khon Kaen (506928)					159.00	Drilled by DMR Rig
D842	Ban Tha Dua Amphoe Kosumphisai Mahasarakham (894027)	18.3		4	12.2-18.3	145.00	Drilled by DMR Rig
F804	Ban Nong Bua Amphoe Muang Khon Kaen	27.4		4	21.3-27.4	165.00	Drilled by DMR Rig

Appendix 1.1.3 Records of water wells drilled by the Department of Mineral Resources (Cont.)

Well No.	Location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing Dia.(") Length(m) Type	Slotted/Screen Interval(m) Type	Ground elev. m. above M.S.L.	Remarks
	(648056)						
F366	Wat Ban Non Swan Amphoe Ban Phai Khon Kaen (638996)	64.0			21.3-33.5,51.8-64	170.00	Drilled by DMR Rig
S649	Ban Nong Kranuan Amphoe Ban Phai Khon Kaen (666994)	44.2			18.3-24.4	171.00	Drilled by DMR Rig
D887	Ban Phaeng Amphoe Kosumphisai Mahasarakham (849991)	21.3			15.2-21.3	150.00	Drilled by DMR Rig
D890	Wat Pa Dong Ruang Amphoe Kosumphisai Mahasarakham (930964)	51.8			15.7-51.8	152.00	Drilled by DMR Rig
D678	Ban Nong Kung Tao A. Kantharawichai Mahasarakham (999890)	42.7			Opne Hole	152.00	Drilled by DMR Rig
D619	Wat Ban Samrong Amphoe Borabu Mahasarakham (916876)	30.5			24.4-30.5	158.00	Drilled by DMR Rig
D870	Ban Na Pho Amphoe Borabu Mahasarakham (765880)	53.3			24.4-53.3	179.00	Drilled by DMR Rig
F701	Ban Na Pho T.Nai Muang A.Ban Phai Khon Kaen (626776)	33.5			27.44-33.54	188.00	Drilled by DMR Rig
D555	Wat Ban Phai Sam Amphoe Borabu Mahasarakham (715746)	61.0			54.9-61.0	212.00	Drilled by DMR Rig
D740	Ban Ba Luang Amphoe Borabu Mahasarakham (795972)	36.6			12.2-18.3	740.00	Drilled by DMR Rig
D739	Ban Thipphayasot Amphoe Borabu Mahasarakham (737874)	36.6			12.2-18.3	198.59	Drilled by DMR Rig
D65	Wat Ban Nong Nae Amphoe Borabu Mahasarakham (765751)	32.4			28.96-41.16	199.00	Drilled by DMR Rig
F396	Ban Nong Ngong Amphoe Borabu Mahasarakham (609905)	76.2					Drilled by DMR Rig
D602	Ban Upparat School A.Kantharwichai Mahasarakham (076894)	30.5			24.4-30.5	155.00	Drilled by DMR Rig
D892	Ban Khok Si Amphoe Kosumphisai Mahasarakham (891852)	30.5			24.4-30.5	151.00	Drilled by DMR Rig
D688	Ban Phong Phot Amphoe Borabu Mahasarakham (939761)	36.6		6	6.09-12.19	186.00	Drilled by DMR Rig
D863	Ban Hua Chang Amphoe Borabu Mahasarakham (865773)	51.2			30.5-51.2	168.00	Drilled by DMR Rig
D866	Ban Nong Chik Amphoe Borabu Mahasarakham (037723)	24.4			18.29-24.4		Drilled by DMR Rig
D839	Wat Ban Don Kloi Amphoe Kosumphisai Mahasarakham	18.3				154.00	Drilled by DMR Rig

Appendix 1.1.3 Records of water wells drilled by the Department of Mineral Resources (Cont.)

Well No.	Location UTM.Grid System	Drilled depth m(ft) Date	Hole Diameter (inches)	Casing Dia.(") Length(m) Type	Slotted/Screen Interval(m) Type	Ground elev. m. above M.S.L.	Remarks
	(921951)						
F272	Wat Sawang A-Ron Amphoe Ban Fhai Khon Kaen (575893)	36.6		6	30.5-36.6		Drilled by DMR Rig
B1060	Ban Nong Ran Ya School A.Ban Phai Khon Kaen (534773)	24.4		4	18.3-24.4	170.00	Drilled by DMR Rig
S722	Ban Nong Kao Noi Amphoe Phai Khon Kaen (564734)	30.5		5	24.4-30.5	171.00	Drilled by DMR Rig
S311	Wat Ban Nong Phak Top Amphoe Ban Phai Khon Kaen (594962)	36.6		6	30.5-36.6	165.00	Drilled by DMR Rig
B1059	Ban Ked Peng Amphoe Ban Fhai Khon Kaen (546825)	24.4		5	18.3-24.5	160.00	Drilled by DMR Rig
B1118	Ban Khon Sak Amphoe Ban Phai Khon Kaen (710881)					206.65	Drilled by DMR Rig
F110	Ban Nonsomboon Amphoe Ban Phai Khon Kaen (609971)					168.00	Drilled by DMR Rig
S233	Ban Khon Sak Amphoe Ban Phai Khon Kaen (710881)					198.65	Drilled by DMR Rig
S473	Ban Khon Sak Amphoe Ban Phai Khon Kaen (710881)					203.97	Drilled by DMR Rig

Appendix 1.2 Lithologic logs of pumped wells drilled by GREP in the Khon Kaen Drainage Basin

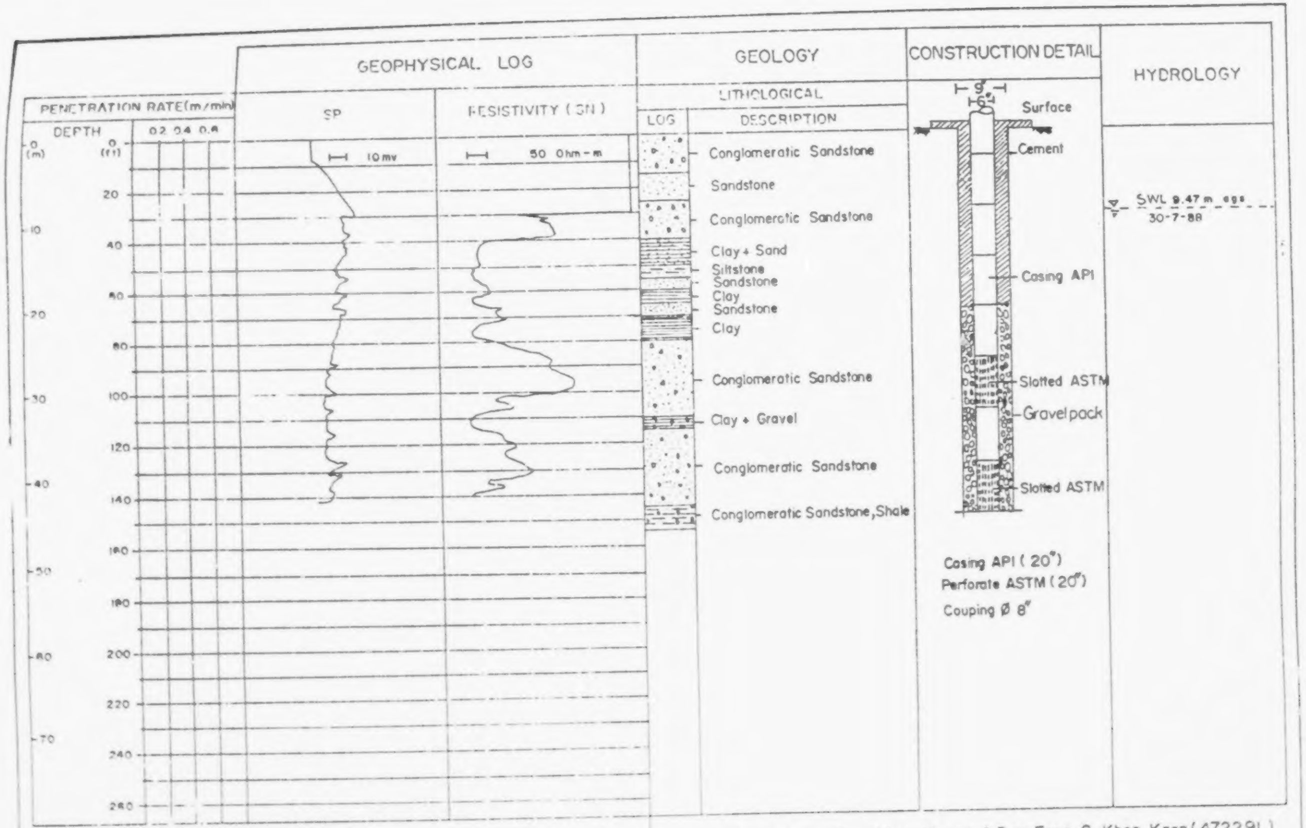

GEOPHYSICAL LOG
GEOLOGY
CONSTRUCTION DETAIL
HYDROLOGY
PENETRATION RATE (m/min)
0.2 0.4 0.6
DEPTH
0 (m)
0 (ft)
SP
10 mv
RESISTIVITY (SN)
50 Ohm-m
LITHOLOGICAL
LOG
DESCRIPTION
Conglomeratic Sandstone
Sandstone
Conglomeratic Sandstone
Clay + Sand
Siltstone
Sandstone
Clay
Sandstone
Clay
Conglomeratic Sandstone
Clay + Gravel
Conglomeratic Sandstone
Conglomeratic Sandstone, Shale
9"
6"
Surface
Cement
Casing API
Slotted ASTM
Gravelpack
Slotted ASTM
Casing API (20")
Perforate ASTM (20")
Couping Ø 8"
SWL 9.47 m ags
30-7-88
10
20
30
40
50
60
70
20
40
60
80
100
120
140
160
180
200
220
240
260

Fig. 4.2 Project : Groundwater Resource Evaluation

Well No : WW1 (F1007 KK 903)

Location : Ban Khok Kwang, A.Ban Fang, C.Khon Kaen (472291)

Status : Production well and testing well

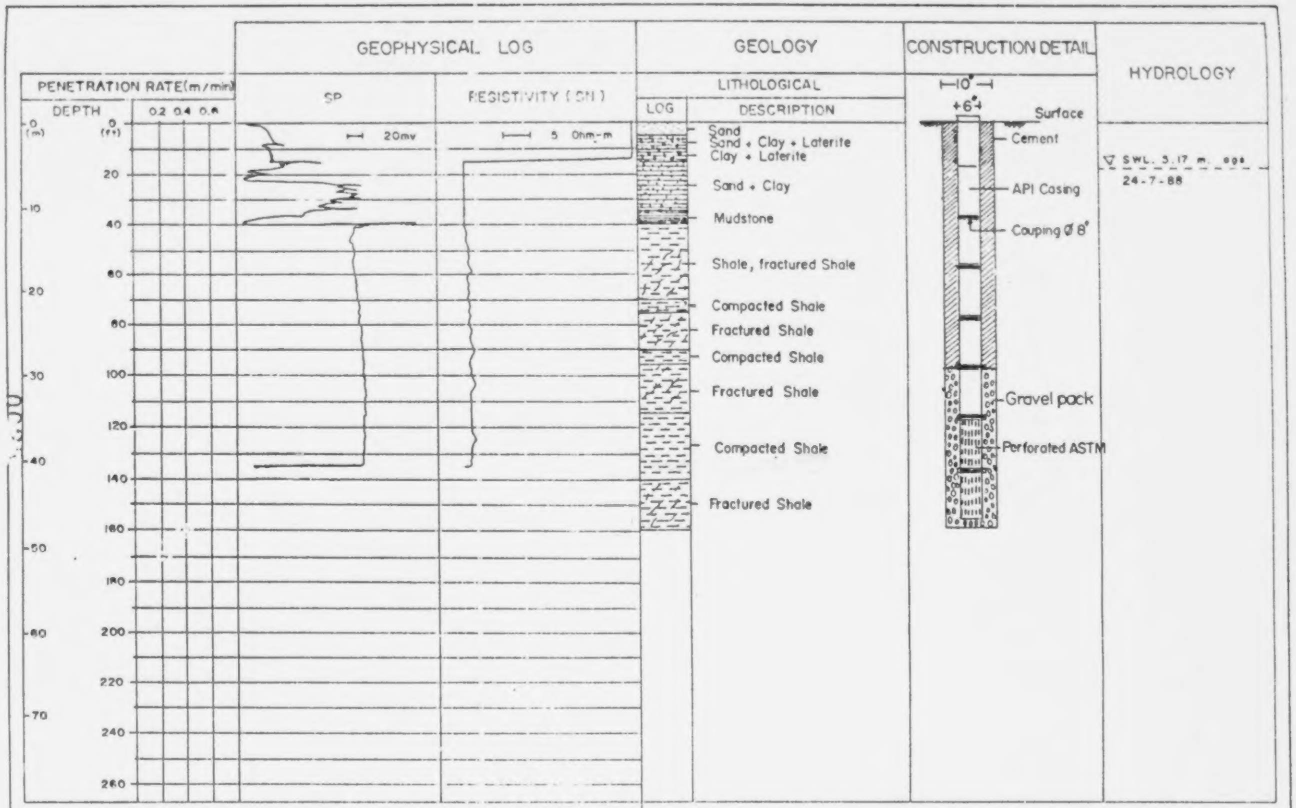

GEOPHYSICAL LOG
GEOLOGY
CONSTRUCTION DETAIL
HYDROLOGY
PENETRATION RATE (m/min)
DEPTH
0 (m)
0 (ft)
0.2 0.4 0.6
SP
20mv
RESISTIVITY (SN)
5 Ohm-m
LITHOLOGICAL
LOG
DESCRIPTION
10
20
30
40
50
60
70
20
40
60
80
100
120
140
160
180
200
220
240
260
Sand
Sand + Clay + Laterite
Clay + Laterite
Sand + Clay
Mudstone
Shale, fractured Shale
Compacted Shale
Fractured Shale
Compacted Shale
Fractured Shale
Compacted Shale
Fractured Shale
10"
6"
Surface
Cement
API Casing
Couping Ø 8"
Gravel pack
Perforated ASTM
SWL. 3.17 m. ags
24-7-88

Fig. 43 Project : Groundwater Resource Evaluation

Well No : WW 2 (Y948 KK 8)

Location : Ban Muang, A. Muang, C. Khon Kaen (542719)

Status : Production well and pump testing well

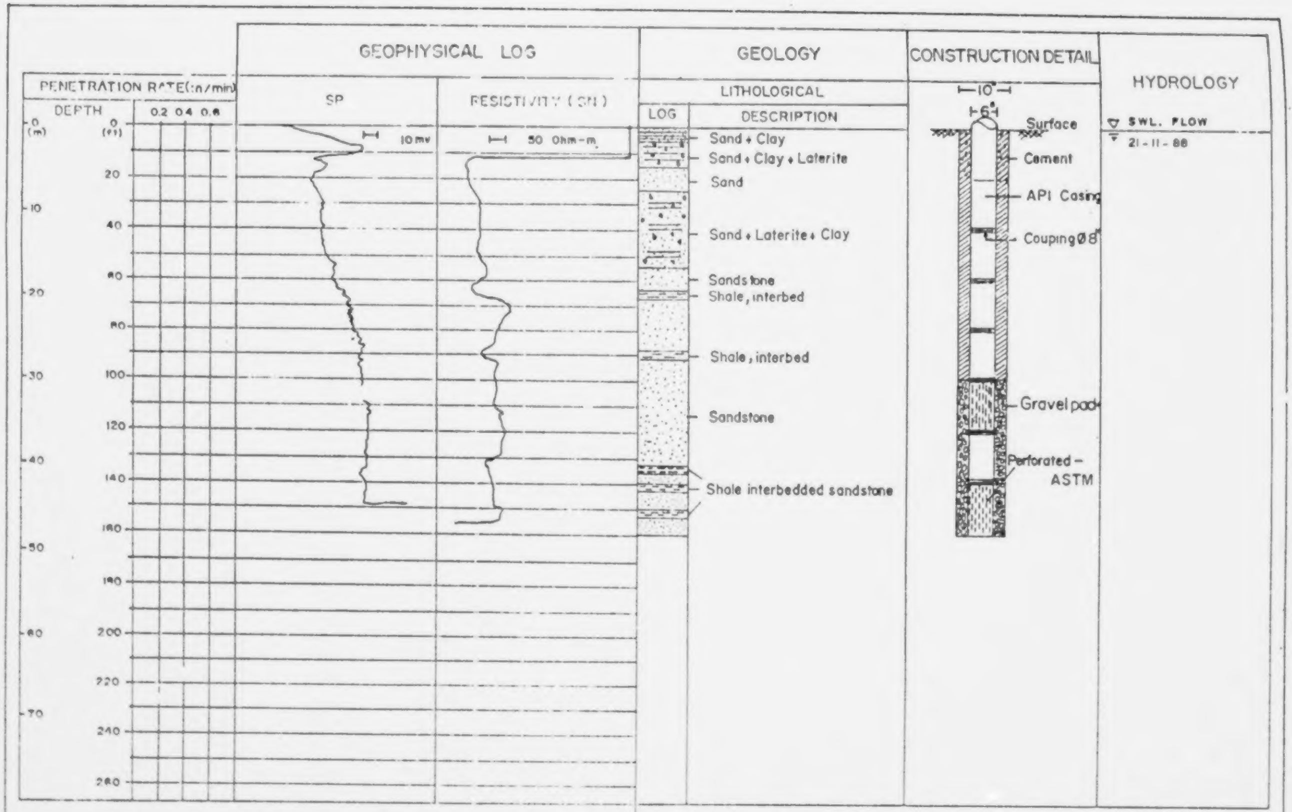

GEOPHYSICAL LOG
GEOLOGY
CONSTRUCTION DETAIL
HYDROLOGY
PENETRATION RATE(m/min)
DEPTH
0.2 0.4 0.6
(m)
(ft)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
10
20
30
40
50
60
70
SP
10 mv
RESISTIVITY (SN)
50 Ohm-m.
LITHOLOGICAL
LOG
DESCRIPTION
Sand + Clay
Sand + Clay + Laterite
Sand
Sand + Laterite + Clay
Sandstone
Shale, interbed
Shale, interbed
Sandstone
Shale interbedded sandstone
10"
6"
Surface
Cement
API Casing
Couping Ø 8"
Gravel pack
Perforated – ASTM
SWL. FLOW
21-11-88

Fig. 4.4 Project : Groundwater Resource Evaluation

Well No : WW 3 (B1128 KK24)

Location : Ban Nong Khai Nun A. Muang C. Khon Kaen (691087)

Status : Production well and pump testing well

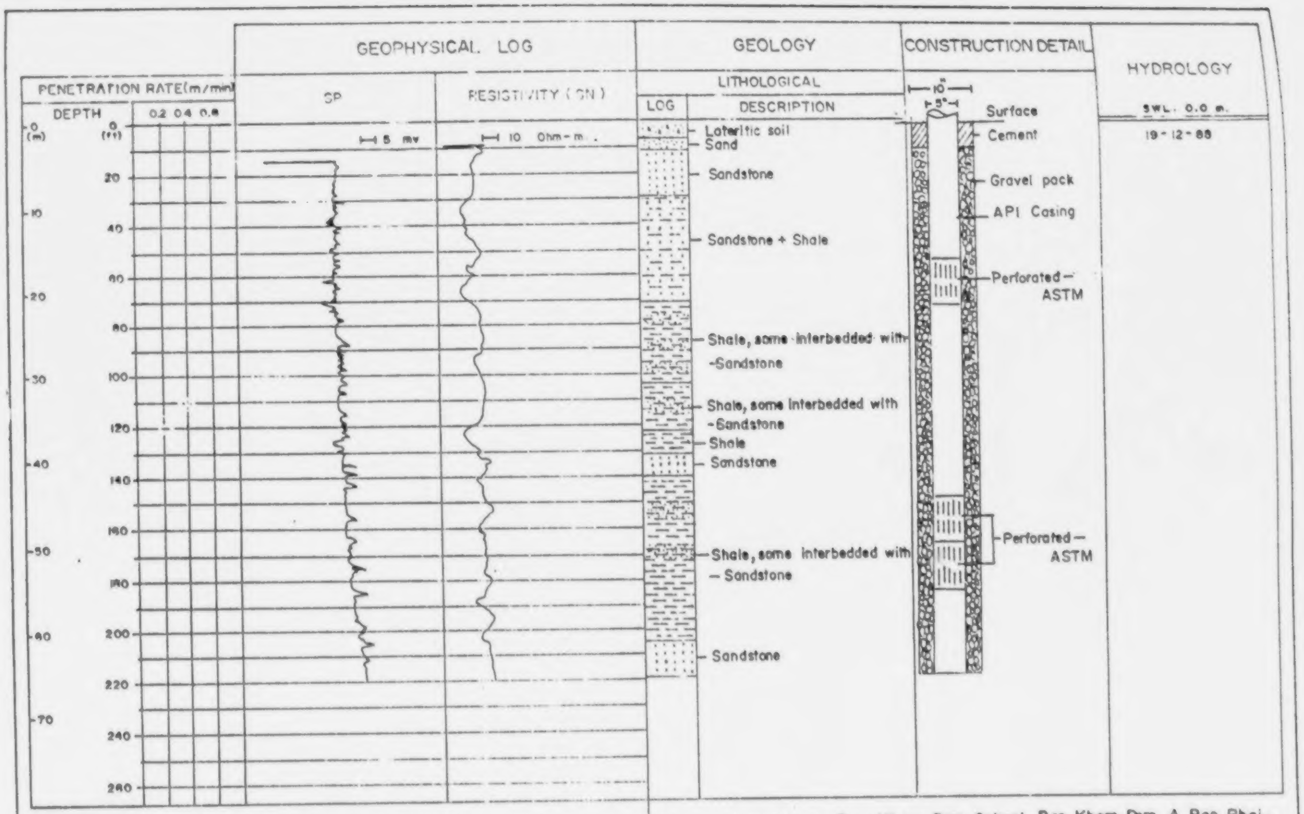

GEOPHYSICAL LOG
SP
RESISTIVITY (SN)
5 mv
10 Ohm-m.
PENETRATION RATE(m/min)
0.2 0.4 0.8
DEPTH
0 (m)
10
20
30
40
50
60
70
0 (ft)
20
40
60
80
100
120
140
160
180
200
220
240
260
GEOLOGY
LITHOLOGICAL
LOG
DESCRIPTION
Lateritic soil
Sand
Sandstone
Sandstone + Shale
Shale, some interbedded with -Sandstone
Shale, some interbedded with -Sandstone
Shale
Sandstone
Shale, some interbedded with – Sandstone
Sandstone
CONSTRUCTION DETAIL
10"
5"
Surface
Cement
Gravel pack
API Casing
Perforated – ASTM
Perforated – ASTM
HYDROLOGY
SWL. 0.0 m.
19-12-88

Fig.4-5 Project : Groundwater Resource Evaluation

Well No : WW8 (S899 KK650)

Location : Ban Kham Pom School, Ban Kham Pom, A. Ban Phai-C. Khon Kaen (651875)

Status : Production well and testing well

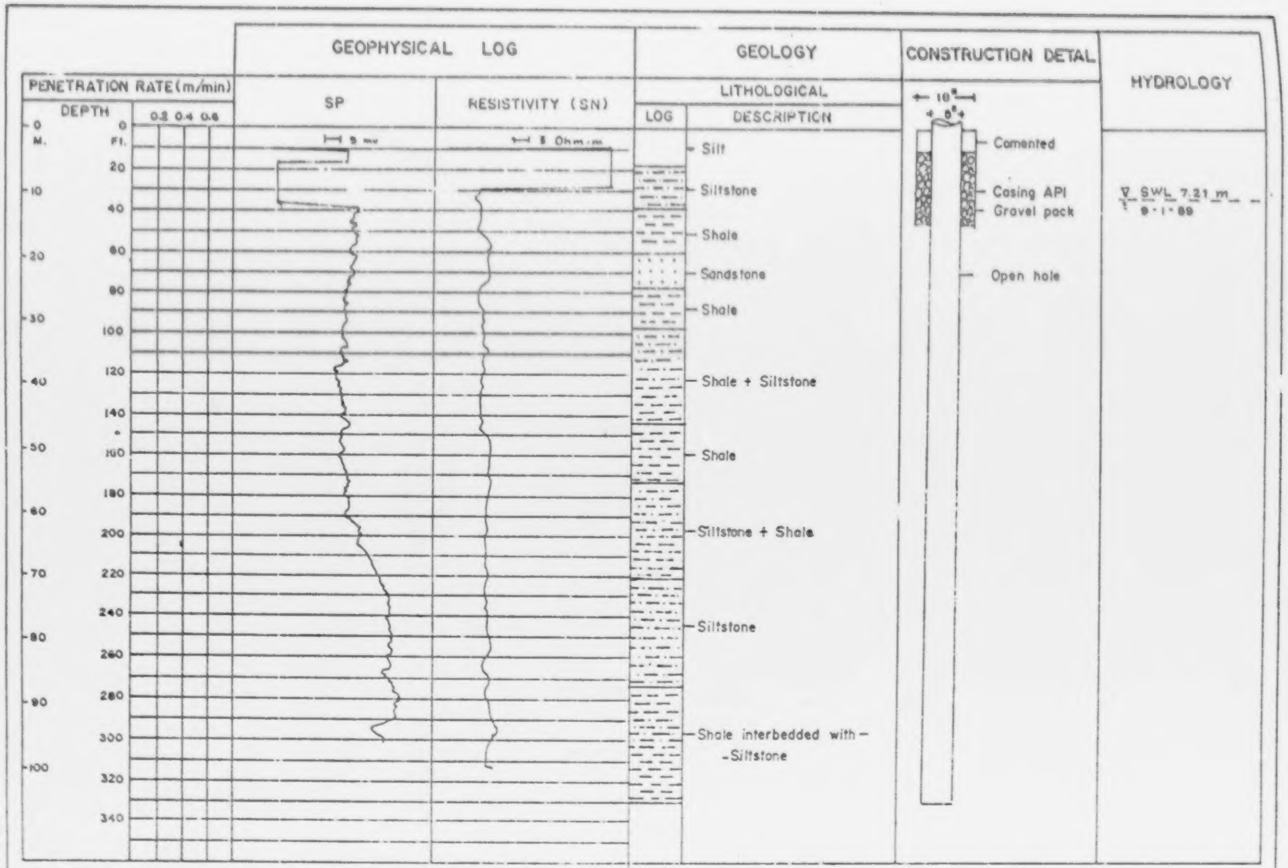

GEOPHYSICAL LOG
GEOLOGY
CONSTRUCTION DETAL
HYDROLOGY
PENETRATION RATE (m/min)
DEPTH
0.2 0.4 0.6
SP
RESISTIVITY (SN)
LITHOLOGICAL
LOG
DESCRIPTION
0 M.
0 Ft.
10
20
30
40
50
60
70
80
90
100
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
5 mv
5 Ohm-m
Silt
Siltstone
Shale
Sandstone
Shale
Shale + Siltstone
Shale
Siltstone + Shale
Siltstone
Shale interbedded with -Siltstone
10"
6"
Cemented
Casing API
Gravel pack
Open hole
SWL 7.21 m
9-1-89

Fig. 4.6 Project : Groundwater Resource Evaluation
Well No : WW 9 (D 1123 MS 619)

Location : Ban Hua khua, A. Borabu, C. Mahasarakham (826756)
Status : Production well and testing well

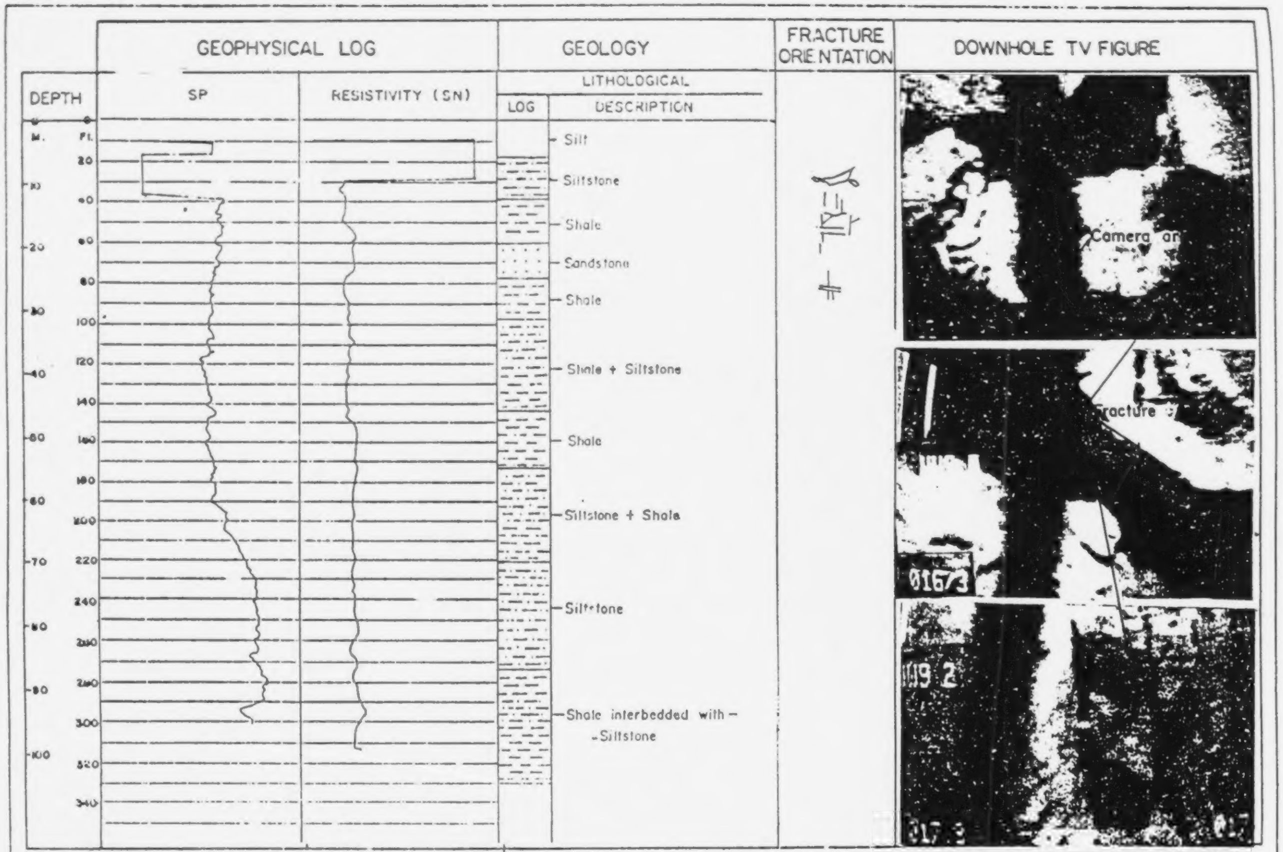

GEOPHYSICAL LOG
GEOLOGY
FRACTURE ORIENTATION
DOWNHOLE TV FIGURE
DEPTH
M.
Ft.
SP
RESISTIVITY (SN)
LITHOLOGICAL
LOG
DESCRIPTION
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
10
20
30
40
50
60
70
80
90
100
Silt
Siltstone
Shale
Sandstone
Shale
Shale + Siltstone
Shale
Siltstone + Shale
Siltstone
Shale interbedded with -
-Siltstone
Camera
Fracture
01673

Fig.4.13 Project : Groundwater Resource Evaluation
Well No : WW 9 (D1123 MS619)

Location : Ban Hua khua, A. Borabu, C. Mahasarakham (826756)
Status : Production well and testing well

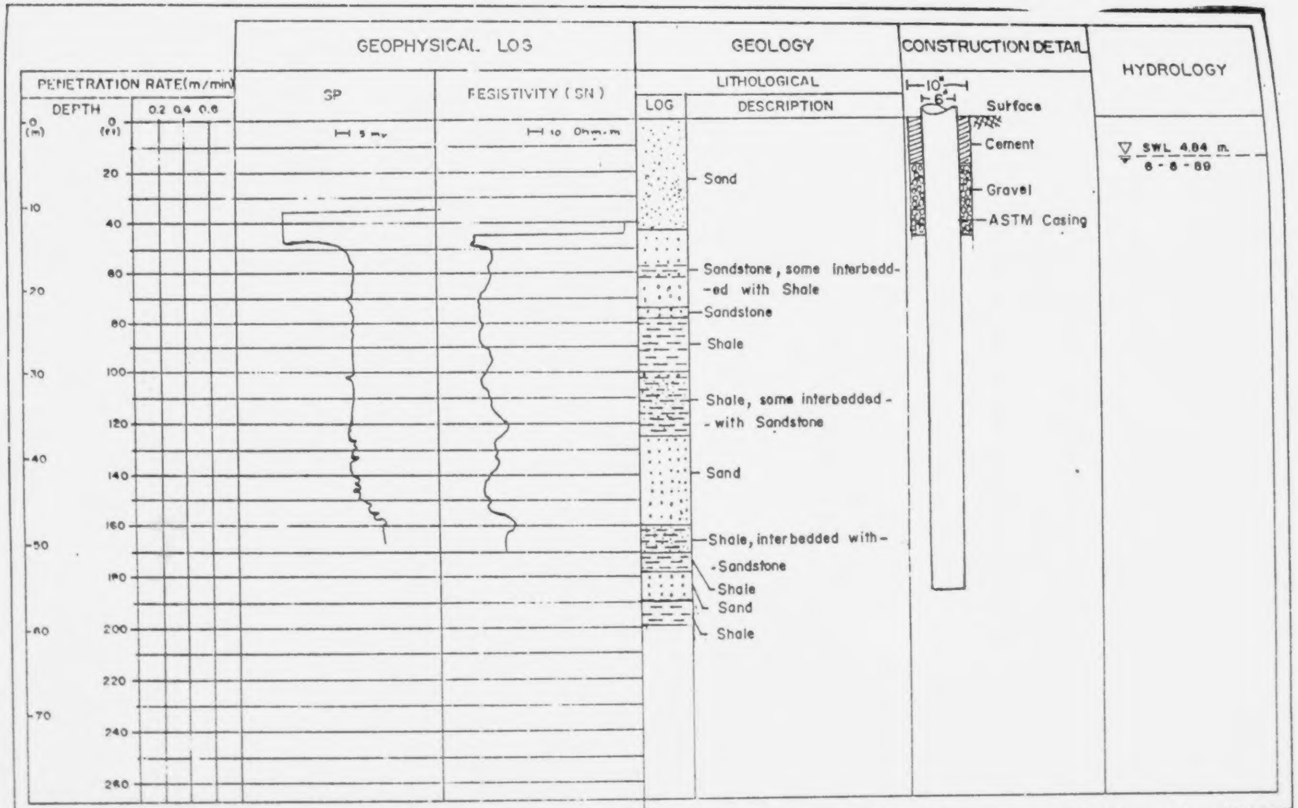

GEOPHYSICAL LOG
GEOLOGY
CONSTRUCTION DETAIL
HYDROLOGY
PENETRATION RATE(m/min)
DEPTH
0.2 0.4 0.6
SP
RESISTIVITY (SN)
LITHOLOGICAL
LOG
DESCRIPTION
0 (m)
0 (ft)
20
10
40
60
20
80
30
100
120
40
140
160
50
180
60
200
220
70
240
260
5 mv
10 Ohm-m
Sand
Sandstone, some interbedd--ed with Shale
Sandstone
Shale
Shale, some interbedded--with Sandstone
Sand
Shale, interbedded with--Sandstone
Shale
Sand
Shale
10"
6"
Surface
Cement
Gravel
ASTM Casing
SWL 4.84 m.
6 - 8 - 89

Fig.4.7 Project : Groundwater Resource Evaluation

Well No : WW 10 (D1122 MS618)

Location : Ban Nong Khaen, A. Borabue, C. Mahasarakham(893827)

Status : Production well and testing well

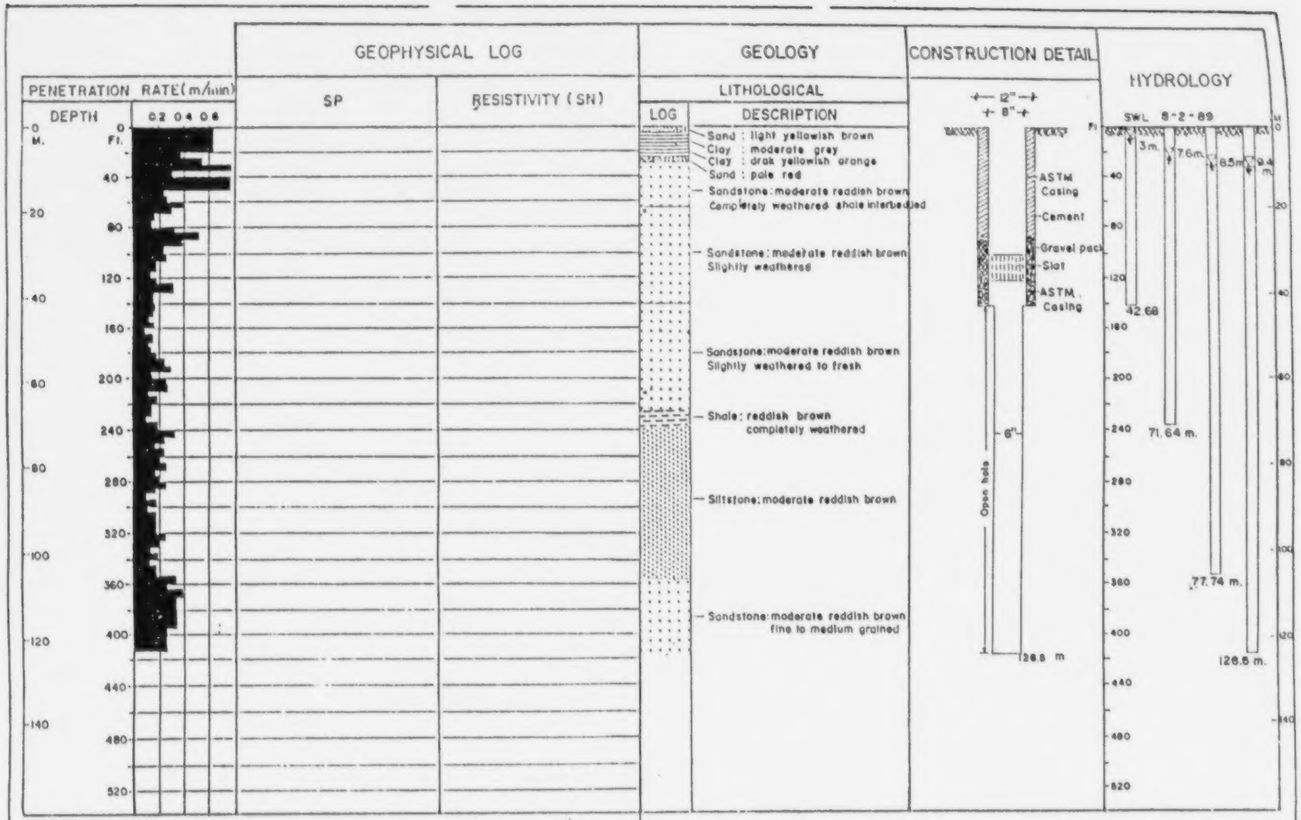


Fig Project : Groundwater Resource Evaluation

Well No : WW 16 (S 911 KK 662)

Location : Ban Thang Phat , A. Ban Phai , C. Khon Kaen (594862)

Status : Production well and testing well

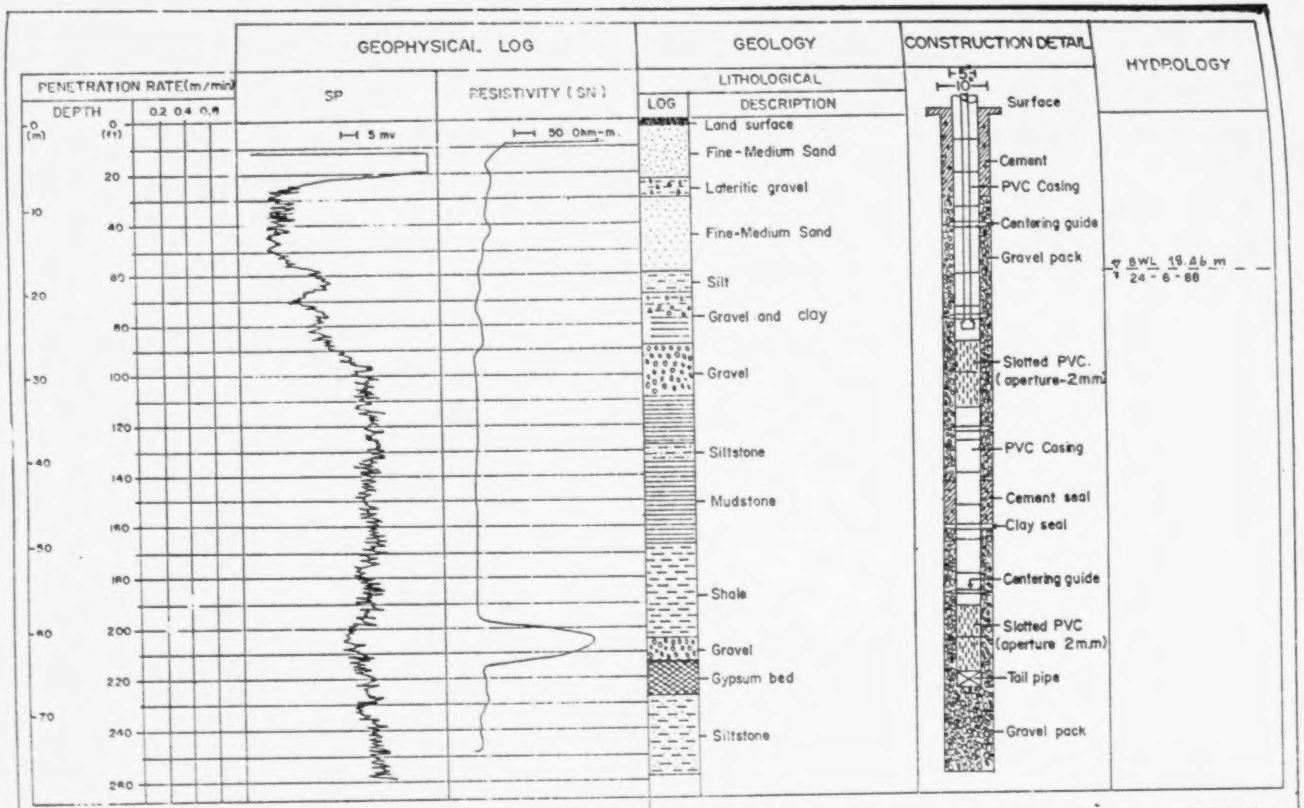

GEOPHYSICAL LOG
GEOLOGY
CONSTRUCTION DETAIL
HYDROLOGY
PENETRATION RATE(m/min)
DEPTH
(m)
(ft)
0.2 0.4 0.6
SP
5 mv
RESISTIVITY (SN)
50 Ohm-m.
LITHOLOGICAL
LOG
DESCRIPTION
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140
160
180
200
220
240
260
Land surface
Fine-Medium Sand
Lateritic gravel
Fine-Medium Sand
Silt
Gravel and clay
Gravel
Siltstone
Mudstone
Shale
Gravel
Gypsum bed
Siltstone
5
10
Surface
Cement
PVC Casing
Centering guide
Gravel pack
Slotted PVC. (aperture-2mm)
PVC Casing
Cement seal
Clay seal
Centering guide
Slotted PVC (aperture 2m.m)
Tail pipe
Gravel pack
SWL 19.46 m
24 - 6 - 88

Fig.4.8 Project : Groundwater Resource Evaluation

Well No : PWKS

Location : Ban Non Muang, A. Muang, C. Khon Kaen (676232)

Status : Production well and pump testing well

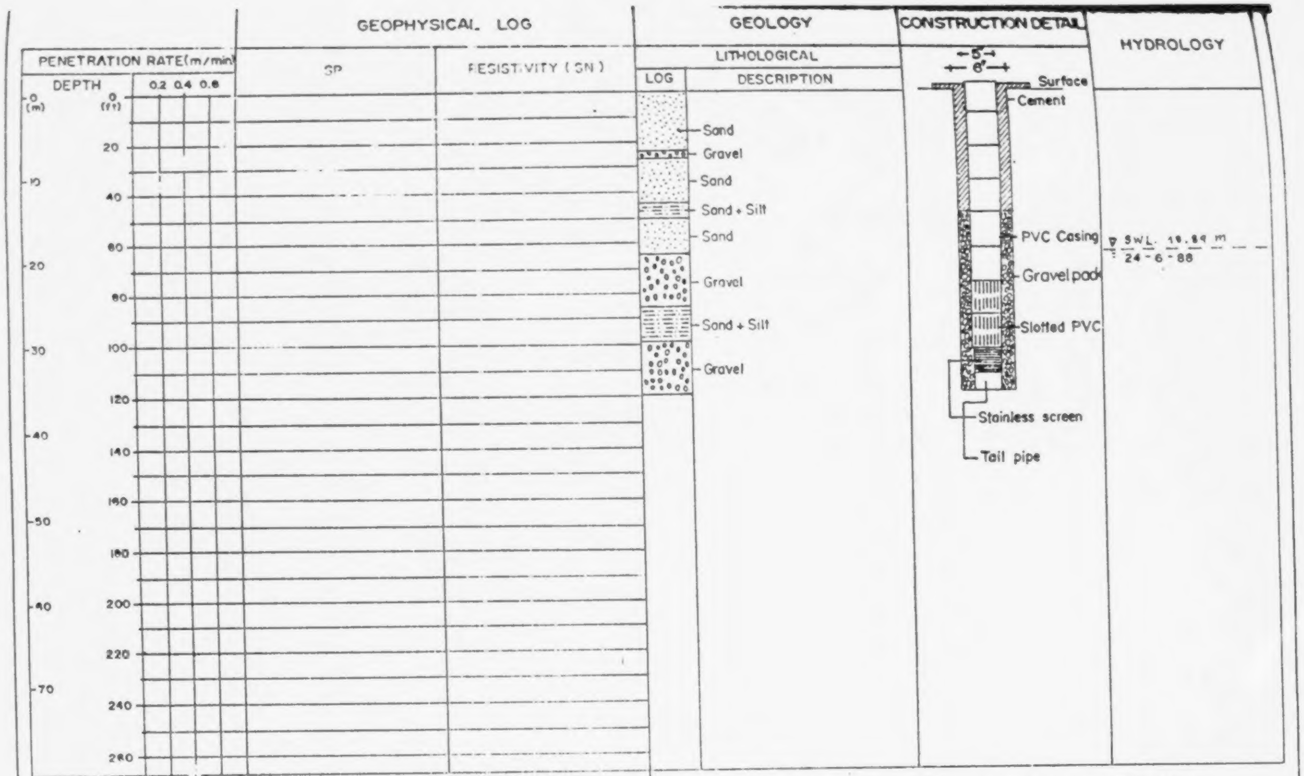

GEOPHYSICAL LOG
GEOLOGY
CONSTRUCTION DETAIL
HYDROLOGY
PENETRATION RATE(m/min)
DEPTH
0 (m)
0 (ft)
0.2 0.4 0.6
SP
RESISTIVITY (SN)
LITHOLOGICAL
LOG
DESCRIPTION
20
10
40
60
20
80
30
100
120
40
140
160
50
180
60
200
220
70
240
260
Sand
Gravel
Sand
Sand + Silt
Sand
Gravel
Sand + Silt
Gravel
5"
6"
Surface
Cement
PVC Casing
Gravel pack
Slotted PVC
Stainless screen
Tail pipe
SWL. 18.89 m
24 - 6 - 88

Fig.49 Project : Groundwater Resource Evaluation

Well No : PWKC

Location : 50m. NE of PWKS, A. Muang C. Khon Kaen .

Status : Production well and pump testing well

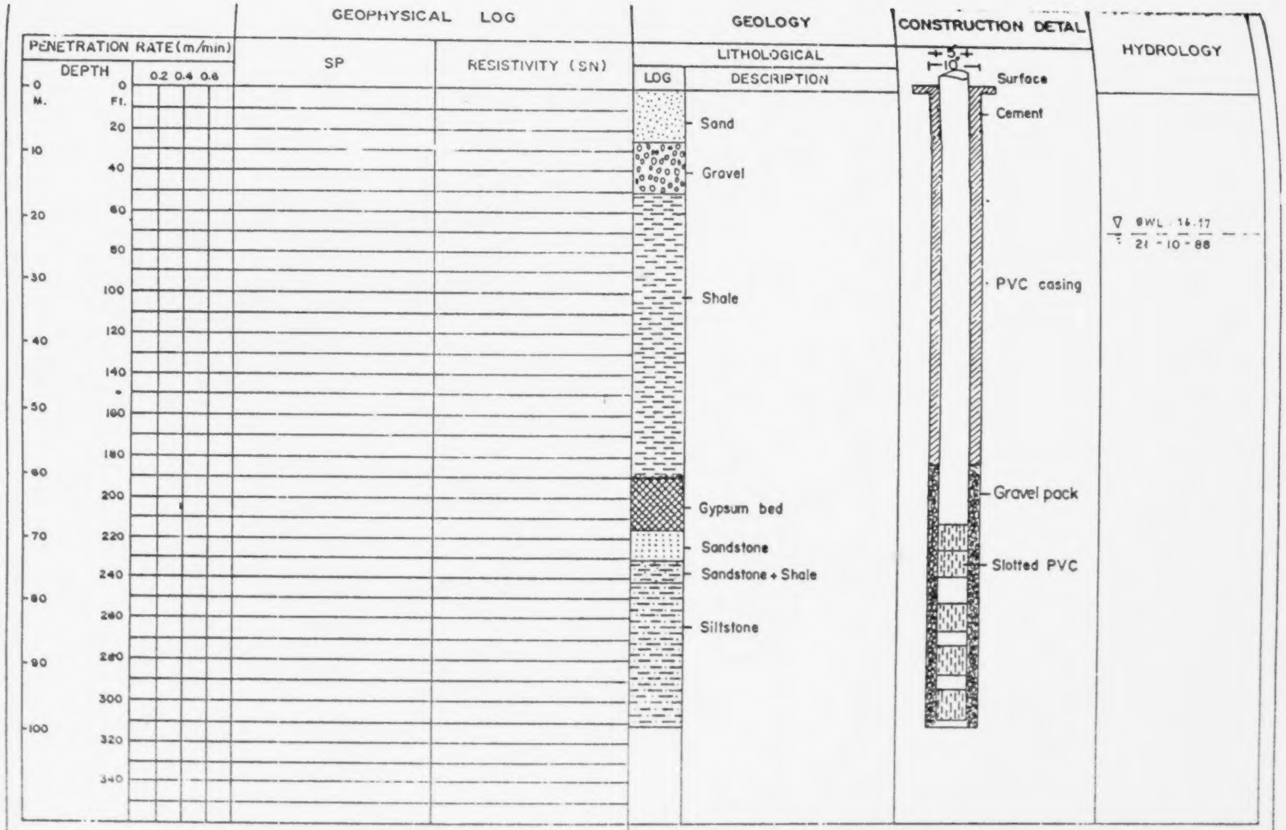

GEOPHYSICAL LOG
PENETRATION RATE (m/min)
DEPTH
M.
Ft.
0.2 0.4 0.6
SP
RESISTIVITY (SN)
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
GEOLOGY
LITHOLOGICAL
LOG
DESCRIPTION
Sand
Gravel
Shale
Gypsum bed
Sandstone
Sandstone + Shale
Siltstone
CONSTRUCTION DETAL
5
10
Surface
Cement
PVC casing
Gravel pack
Slotted PVC
HYDROLOGY
SWL 16.17
21 - 10 - 88

Fig. 4.10 Project : Groundwater Resource Evaluation
Well No : PWTW

Location : 150m. W of PWKS A. Muang C. Khon Kaen.
Status : Production well and pump testing well

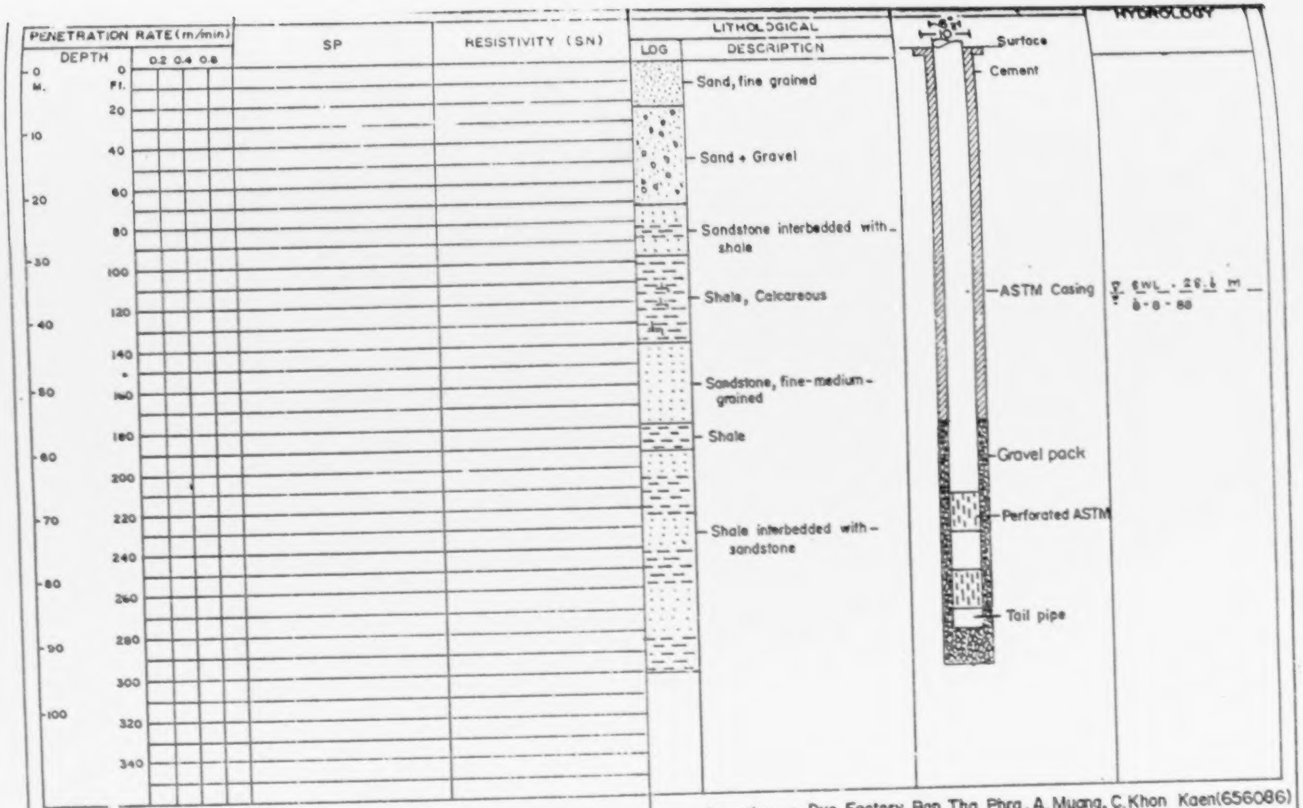

PENETRATION RATE (m/min)
DEPTH
0 M.
0 Ft.
0.2 0.4 0.6
SP
RESISTIVITY (SN)
LITHOLOGICAL
LOG
DESCRIPTION
HYDROLOGY
10
20
30
40
50
60
70
80
90
100
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
Sand, fine grained
Sand + Gravel
Sandstone interbedded with shale
Shale, Calcareous
Sandstone, fine-medium-grained
Shale
Shale interbedded with sandstone
6"
10"
Surface
Cement
ASTM Casing
Gravel pack
Perforated ASTM
Tail pipe
SWL - 26.6 m
6 - 8 - 88

Fig.4.11 Project : Groundwater Resource Evaluation
Well No : PWDF

Location : Dye Factory, Ban Tha Phra, A. Muang, C. Khon Kaen(656086)
Status : Production well and testing well

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	F1040	A	244.6	1809.5	89/03/00		193.00																
2	F1040	A	244.6	1809.5	89/04/09		193.00																
3	F1040	A	244.6	1809.5	89/05/10		193.00		6.0		200	5.8	242	9.3	6.9	24.0	1.9	0.13	73.0	27.0	5.7	0.0	111
4	F1040	A	244.6	1809.5	89/06/06		193.00		6.3		300	5.9	217	11.0	5.3	22.0	2.2	0.22	67.0	29.0	5.9	0.7	109
5	F1040	A	244.6	1809.5	89/07/11		193.00		6.3	33.9	300	5.7	255	19.0	6.5	22.0	2.2	4.80	100.0	29.0	6.7	0.3	134
6	F1040	A	244.6	1809.5	89/08/07		193.00		6.6	28.7	500	6.6	398	63.0	0.4	22.0	2.5	1.10	187.0	27.0	1.5	0.9	207
7	F1040	A	244.6	1809.5	89/09/13		193.00		7.2		200	6.1	223	13.0	3.4	21.0	2.5	0.75	64.0	27.0	7.6	0.8	107
8	F1040	A	244.6	1809.5	89/10/19	8.88	193.00	184.12	7.2		200	5.7	217	8.6	8.3	21.0	2.4	0.66	73.0	26.0	5.6	0.0	190
9	F1040	A	244.6	1809.5	89/11/07	9.11	193.00	183.89	7.6		200	7.8	376	39.0	7.0	22.0	1.6	2.10	158.0	26.0	6.2	0.0	179
10	F1040	A	244.0	1809.5	89/12/19	9.30	193.00	183.70	8.0		400	6.0	222	11.0	7.4	19.0	1.9	78.00	87.0	28.0	0.0	0.0	110
11	F1040	A	244.6	1809.5	90/01/16		193.00		6.7		200	6.0	219	8.6	11.0	20.0	1.3	0.77	70.0	28.0	5.4	0.5	109
12	F1040	A	244.6	1809.5	90/02/15	9.57	193.00	183.43	6.3		200	6.6	221	8.5	9.4	18.0	1.6	4.40	81.0	26.0	6.0	0.2	110
13	F1040	A	244.6	1809.5	90/03/14	6.21	193.00		6.7		100	5.5	220	10.0	5.4	27.0	1.8	0.94	68.0	31.0	9.8	0.0	118
14	F186	A	264.2	1821.5	89/03/15	11.17	190.00	178.83	6.4		1800	6.3	1570	156.0	49.0	118.0	3.0	0.24	126.0	256.0	324.0	24.0	992
15	F186	A	264.2	1821.5	89/04/09	10.95	190.00	179.05	6.2		1400	7.3	1680	158.0	51.0	120.0	2.0	0.48	133.0	262.0	328.0	20.0	1060
16	F186	A	264.2	1821.5	89/05/09	18.57	190.00	171.43	6.3		1700	6.2	1590	150.0	49.0	111.0	1.8	1.80	130.0	245.0	343.0	15.0	979
17	F186	A	264.2	1821.5	89/06/09	10.60	190.00	179.40	6.2		1400	6.2	1640	154.0	49.0	113.0	2.1	0.61	126.0	246.0	265.0	17.0	909
18	F186	A	264.2	1821.5	89/07/11	10.22	190.00	179.78	6.6	27.2	1700	6.0	1580	151.0	46.0	104.0	2.1	1.10	130.0	243.0	358.0	23.0	992
19	F186	A	264.2	1821.5	89/08/09		190.00		7.0	28.0	1700	6.0	1610	158.0	46.0	109.0	2.5	1.00	129.0	249.0	843.0	17.0	988
20	F186	A	264.2	1821.5	89/09/09		190.00		7.2	31.3	1800	6.4	1640	217.0	2.9	115.0	2.7	2.00	112.0	242.0	363.0	23.0	1020
21	F186	A	264.2	1821.5	89/10/18		190.00		7.1		1800	6.4	1580	146.0	61.0	116.0	1.7	0.54	129.0	247.0	318.0	22.0	975
22	F186	A	264.2	1821.5	89/11/03		190.00		0.8		1700	6.7	1580	148.0	55.0	113.0	2.0	0.31	129.0	242.0	364.0	25.0	1010
23	F186	A	264.2	1821.5	89/12/13		190.00																
24	F186	A	264.2	1821.5	90/01/16		190.00		7.1		1600	6.4	1680	155.0	47.0	109.0	1.4	1.00	137.0	249.0	349.0	23.0	1000
25	F186	A	264.2	1821.5	90/02/06		190.00		6.5		1500	6.8	1670	154.0	49.0	109.0	1.9	1.80	135.0	208.0	389.0	27.0	1010
26	F186	A	263.4	1814.9	90/03/14			190.00	7.1		1500	7.6	1570	150.0	53.0	108.0	1.8	2.40	131.0	235.0	346.0	24.0	982
27	F401	A	263.4	1814.9	89/03/13		155.00		7.7		700	7.7	613	25.0	2.7	108.0	3.5	0.00	364.0	25.0	0.0	0.0	343
28	F401	A	263.4	1814.9	89/04/08		155.00		7.6		500	7.7	602	24.0	3.4	177.0	0.9	0.00	362.0	22.0	0.4	0.0	340
29	F401	A	263.4	1814.9	89/05/11		155.00		7.4		680	7.7	615	23.0	3.7	119.0	1.1	0.09	364.0	22.0	0.0	0.0	348
30	F401	A	263.4	1814.9	89/05/24		155.00		8.0		600												
31	F401	A	263.4	1814.9	89/06/09		155.00		7.1		600	7.7	617	28.0	1.3	121.0	1.1	0.00	367.0	22.0	0.6	0.0	354
32	F401	A	263.4	1814.9	89/07/09		155.00		6.2	27.8	700	7.7	604	26.0	2.7	117.0	1.2	0.13	362.0	22.0	0.0	0.6	348
33	F401	A	263.4	1814.9	89/08/07		155.00		6.8	30.7	500	7.2	607	25.0	2.5	116.0	1.2	0.13	369.0	25.0	0.5	0.2	353
34	F401	A	263.4	1814.9	89/09/16		155.00		7.6		700	7.6	624	14.0	4.9	119.0	1.2	0.11	347.0	23.0	0.0	0.5	333
35	F401	A	263.4	1814.9	89/10/19		155.00		7.6		600	7.6	607	24.0	4.3	123.0	0.9	0.00	378.0	24.0	0.0	1.6	357
36	F401	A	263.4	1814.9	89/11/18		155.00		7.9		700	7.9	610	25.0	5.6	116.0	0.9	0.00	374.0	25.0	0.0	0.4	357
37	F401	A	263.4	1814.9	89/12/00		155.00																
38	F401	A	263.4	1814.9	90/01/15		155.00		6.8		600	8.2	637	20.0	3.4	120.0	0.6	0.00	348.0	26.0	0.0	0.0	342
39	F401	A	263.4	1814.9	90/02/16		155.00		7.7		600	7.8	648	21.0	6.0	115.0	0.7	0.17	364.0	28.0	0.0	2.0	351
40	F401	A	263.4	1814.9	90/03/08		155.00		6.9		600	8.1	618	22.0	3.6	114.0	0.7	0.00	353.0	26.0	1.3	0.0	341
41	F459	A	253.5	1818.3	89/03/10		172.00		6.6		6200	6.5	5420	694.0	105.0	282.0	6.0	1.30	421.0	1600.0	23.0	182.0	3080
42	F459	A	253.5	1818.3	89/04/09		172.00		6.4		4500	6.7	5800	690.0	107.0	300.0	6.0	0.47	414.0	1590.0	22.0	383.0	3310
43	F459	A	253.5	1818.3	89/05/09		172.00		6.4		5200	6.8	5600	688.0	99.0	280.0	4.5	3.10	406.0	1540.0	20.0	222.0	3060
44	F459	A	253.5	1818.3	89/06/06		172.00		6.3		4400	6.6	5310	600.0	71.0	290.0	4.9	2.00	422.0	1420.0	28.0	197.0	2820
45	F459	A	253.5	1818.3	89/07/11		172.00		6.5	29.7	5600	6.5	5430	668.0	89.0	280.0	5.3	6.90	423.0	1510.0	28.0	268.0	3060
46	F459	A	253.5	1818.3	89/08/09		172.00		7.2	31.4	5800	6.8	5440	652.0	99.0	257.0	6.2	8.30	417.0	1470.0	26.0	212.0	2920
47	F459	A	253.5	1818.3	89/09/12		172.00		7.2		6500	6.6	5660	702.0	80.0	285.0	5.4	6.90	378.0	1520.0	31.0	115.0	2920
48	F459	A	253.5	1818.3	89/10/19		172.00		7.3		7100	6.6	7140	836.0	226.0	373.0	8.6	3.20	388.0	2310.0	35.0	188.0	6290
49	F459	A	253.5	1818.3	89/11/03		172.00		7.2		6900	7.1	6420	788.0	122.0	327.0	6.5	1.80	326.0	1910.0	34.0	280.0	3640
50	F459	A	253.5	1818.3	89/12/19		172.00		7.9		5100	6.7	5320	622.0	104.0	289.0	4.3	3.30	413.0	1400.0	32.0	248.0	2900
51	F459	A	253.5	1818.3	90/01/16		172.00		6.1		4500	6.7	5630	679.0	114.0	285.0	3.5	1.20	405.0	1540.0	29.0	98.0	2950
52	F459	A	253.5	1818.3	90/02/15		172.00		7.0		3900	6.6	5240	618.0	95.0	267.0	3.9	8.40	376.0	1400.0	26.0	208.0	2810
53	F459	A	253.5	1818.3	90/03/14		172.00		6.8		4000	6.6	5510	651.0	101.0	286.0	3.1	0.00	411.0	1440.0	26.0	137.0	2840
54	F480	A	252.6	1815.3	89/03/10	2.44	175.00	172.56	7.0		5300	7.0	4720	240.0	68.0	628.0	9.3	0.24	394.0	1380.0	22.0	23.0	2570
55	F480	A	252.6	1815.3	89/04/09		175.00		7.0		3700	7.1	4680	219.0	58.0	600.0	8.5	0.10	403.0	1270.0	25.0	38.0	2420
56	F480	A	252.6	1815.3	89/05/09		175.00		7.0		4400	7.1	4660	257.0	46.0	620.0	6.9	0.00	399.0	1290.0	18.0	34.0	2470

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
57	F480	A	252.6	1815.3	89/06/06	2.56	175.00	172.44	6.9		3900	7.2	4610	215.0	56.0	580.0	8.0	0.08	409.0	1240.0	31.0	41.0	2370
58	F480	A	252.6	1815.3	89/07/11		175.00		6.6	29.6	4800	6.9	4620	266.0	24.0	640.0	8.5	0.00	411.0	1260.0	32.0	48.0	2480
59	F480	A	252.6	1815.3	89/08/09		175.00		6.9	30.4	5100	7.4	4870	256.0	51.0	627.0	9.5	0.00	414.0	1300.0	35.0	57.0	2540
60	F480	A	252.6	1815.3	89/09/12		175.00		7.8		5600	6.9	5100	270.0	60.0	679.0	9.7	0.00	395.0	1370.0	38.0	32.0	2660
61	F480	A	252.6	1815.3	89/10/19		175.00		7.3		5100	7.3	4910	205.0	77.0	662.0	8.9	0.00	353.0	1320.0	44.0	57.0	2550
62	F480	A	252.6	1815.3	89/11/03		175.00		7.3		5000	7.4	5010	241.0	39.0	673.0	6.6	0.45	347.0	1280.0	47.0	67.0	2520
63	F480	A	252.6	1815.3	89/12/19		175.00		7.3		5000	7.2	4740	228.0	50.0	654.0	8.5	0.00	349.0	1300.0	44.0	36.0	2500
64	F480	A	252.6	1815.3	90/01/16		175.00		8.1		4300												
65	F480	A	252.6	1815.3	90/02/15		175.00		6.9		3700	7.3	5040	258.0	58.0	657.0	6.9	0.09	376.0	1410.0	26.0	26.0	2630
66	F480	A	252.6	1815.3	90/03/14		175.00		6.7		3600	7.5	4650	273.0	39.0	621.0	4.9	0.00	409.0	1240.0	26.0	24.0	2430
67	F488	A	260.6	1822.4	89/03/15	3.43	170.00	166.57	6.6		100	6.2	156	11.0	6.8	7.9	2.7	5.30	75.0	15.0	0.8	0.4	81
68	F488	A	260.6	1822.4	89/04/09	3.67	170.00	166.33	6.4		100	6.3	161	10.0	6.3	9.2	2.6	8.60	73.0	12.0	9.8	1.1	88
69	F488	A	260.6	1822.4	89/05/09	3.46	170.00	166.54	6.7		300	6.1	140	7.7	5.3	9.8	2.2	23.00	45.0	11.0	12.0	0.0	71
70	F488	A	260.6	1822.4	89/06/09	3.35	170.00	166.65	6.4		300	6.2	136	11.0	3.4	12.0	2.2	29.00	73.0	8.7	1.0	0.5	75
71	F488	A	260.6	1822.4	89/07/10	3.04	170.00	166.96	6.6	27.4	200	5.9	158	11.0	5.7	9.1	2.2	16.00	83.0	8.7	3.5	0.6	82
72	F488	A	260.6	1822.4	89/08/09	3.12	170.00	166.88	7.8	27.9	200	5.7	148	10.0	7.3	9.4	2.7	19.00	85.0	9.5	3.7	0.3	85
73	F488	A	260.6	1822.4	89/09/09	2.80	170.00	167.20	7.0	31.5	200	6.5	154	11.0	6.3	8.0	3.2	23.00	77.0	5.8	2.6	0.7	75
74	F488	A	260.6	1822.4	89/10/19	2.16	170.00	167.84	7.1		200	6.7	135	9.4	6.6	7.3	2.2	25.00	79.0	5.8	0.0	0.2	70
75	F488	A	260.6	1822.4	89/11/03	1.94	170.00	168.06	7.3		200	6.8	122	12.0	3.5	7.5	2.1	28.00	72.0	7.4	0.0	0.0	68
76	F488	A	260.6	1822.4	89/12/13	2.05	170.00	167.95	7.9		200	6.1	131	9.1	9.9	4.8	2.8	50.00	72.0	7.8	1.8	0.5	73
77	F488	A	260.6	1822.4	90/01/16	2.50	170.00	167.50	6.8		100	6.6	133	8.8	6.9	5.1	1.4	4.00	66.0	7.8	4.7	0.0	66
78	F488	A	260.6	1822.4	90/02/15	2.61	170.00	167.39	7.0		200	6.5	122	6.6	8.2	5.4	1.8	0.09	66.0	11.0	0.0	0.4	66
79	F488	A	260.6	1822.4	90/03/14	2.74	170.00		7.0		300	6.4	139	9.1	9.8	6.1	1.8	14.00	78.0	7.9	3.3	0.5	77
80	F532	A	257.9	1834.1	89/03/09		213.00		7.3		819	7.3	844	70.0	16.0	112.0	3.0	0.21	586.0	3.6	3.4	0.4	497
81	F532	A	257.9	1834.1	89/04/02		213.00		7.3		800	7.7	783	80.0	15.0	109.0	2.9	0.37	528.0	4.4	2.6	0.0	444
82	F532	A	257.9	1834.1	89/05/02		213.00		6.9		700	8.2	558	10.0	16.0	110.0	2.5	0.44	329.0	4.4	4.8	0.6	327
83	F532	A	257.9	1834.1	89/06/01		213.00		7.0		900	7.2	844	85.0	1.1	107.0	1.5	0.37	584.0	3.6	3.3	0.0	489
84	F532	A	257.9	1834.1	89/07/05		213.00		6.3	24.3	900	7.1	853	74.0	13.0	108.0	2.6	0.29	589.0	2.8	2.4	0.3	494
85	F532	A	257.9	1834.1	89/08/02		213.00		6.4	31.5	1000	7.2	899	79.0	12.0	106.0	2.7	0.20	588.0	4.0	3.3	0.5	497
86	F532	A	257.9	1834.1	89/09/00		213.00																
87	F532	A	257.9	1834.1	89/10/09		213.00		7.6		900	7.4	869	74.0	13.0	110.0	3.1	0.27	589.0	3.5	2.2	0.8	497
88	F532	A	257.9	1834.1	89/11/09		213.00		7.6		900	8.0	886	46.0	24.0	111.0	2.2	0.20	548.0	4.3	2.6	0.0	460
89	F532	A	257.9	1834.1	89/12/09		213.00		7.8		800	7.2	901	75.0	18.0	109.0	2.6	0.12	586.0	2.3	2.5	0.5	498
90	F532	A	257.9	1834.1	90/01/09		213.00		7.4		400	7.2	835	72.0	16.0	106.0	1.6	0.25	579.0	1.2	2.7	0.7	485
91	F532	A	257.9	1834.1	90/02/06		213.00		6.4		600	7.7	872	72.0	16.0	106.0	1.9	0.27	584.0	0.4	2.9	0.7	488
92	F532	A	257.9	1834.1	90/03/07		213.00		7.9		700	7.6	896	74.0	16.0	105.0	1.7	0.22	589.0	6.9	2.5	0.8	497
93	F564	A	258.3	1800.5	89/03/11	12.25	160.00	147.75	7.3		800	7.6	756	62.0	12.0	97.0	2.3	0.95	461.0	30.0	2.2	1.4	434
94	F564	A	258.3	1800.5	89/04/10	13.33	160.00	146.67	7.0		700	7.4	771	61.0	11.0	103.0	1.8	0.65	464.0	28.0	6.6	0.3	441
95	F564	A	258.3	1800.5	89/05/10	13.02	160.00	146.98	5.8		700	7.4	753	59.0	10.0	104.0	1.3	2.10	460.0	25.0	1.8	0.0	428
96	F564	A	258.3	1800.5	89/06/06	11.80	160.00	148.20	7.2		700	7.7	747	64.0	9.6	96.0	1.5	7.50	464.0	25.0	0.5	0.4	426
97	F564	A	258.3	1800.5	89/07/10	11.11	160.00	148.89	6.4	30.4	800	7.1	750	67.0	8.5	97.0	1.6	18.00	458.0	28.0	0.6	0.3	429
98	F564	A	258.3	1800.5	89/08/09	10.87	160.00	149.13	6.9	27.8	800	7.3	761	65.0	7.4	93.0	1.6	7.20	445.0	30.0	1.7	1.2	418
99	F564	A	258.3	1800.5	89/09/13	9.70	160.00	150.30	7.4		900	7.1	833	86.0	12.0	82.0	1.5	8.20	442.0	43.0	0.1	1.2	444
100	F564	A	258.3	1800.5	89/10/18	9.77	160.00	150.23	7.2		900	7.6	776	62.0	14.0	98.0	1.7	6.90	462.0	31.0	0.0	0.0	434
101	F564	A	258.3	1800.5	89/11/07	10.39	160.00	149.61	7.2		800	7.4	834	62.0	15.0	101.0	1.2	3.50	471.0	29.0	1.9	0.0	441
102	F564	A	258.3	1800.5	89/12/13	11.61	160.00	148.39	7.4		800	7.5	795	70.0	14.0	95.0	1.6	2.70	463.0	38.0	2.4	0.0	450
103	F564	A	258.3	1800.5	90/01/17	15.25	160.00	144.75	6.7		700	8.0	735	53.0	10.0	94.0	0.9	6.10	420.0	31.0	0.0	0.4	395
104	F564	A	258.3	1800.5	90/02/16	12.73	160.00	147.27	6.6		600	7.6	756	66.0	11.0	89.0	1.1	4.30	454.0	30.0	2.2	0.0	423
105	F564	A	258.3	1800.5	90/03/14	12.83	160.00		7.2		700	7.4	703	59.0	13.0	74.0	0.8	0.05	385.0	39.0	0.5	0.3	376
106	F626	A	238.3	1809.7	89/03/11	7.13	220.00	212.87	6.8		3300	7.0	2720	307.0	68.0	160.0	19.0	6.50	558.0	438.0	68.0	534.0	1870
107	F626	A	238.3	1809.7	89/04/09	12.10	220.00	207.90	6.7		1400	7.0	2010	166.0	41.0	160.0	11.0	3.30	413.0	286.0	0.5	210.0	1080
108	F626	A	238.3	1809.7	89/05/09	8.45	220.00	211.55	6.8		2100	7.1	2110	182.0	59.0	158.0	11.0	1.10	417.0	297.0	39.0	227.0	1180
109	F626	A	238.3	1809.7	89/06/05	7.88	220.00	212.12	6.6		2300	7.3	2220	204.0	49.0	150.0	17.0	2.60	162.0	367.0	77.0	425.0	1370
110	F626	A	238.3	1809.7	89/07/11	6.08	220.00	213.92	6.5	29.8	2900	6.8	2720	313.0	34.0	138.0	17.0	4.30	573.0	359.0	70.0	439.0	1650
111	F626	A	238.3	1809.7	89/08/09	5.30	220.00	214.70	6.5	29.9	2900	7.1	2600	278.0	36.0	128.0	23.0	4.10	441.0	353.0	79.0	429.0	1540
112	F626	A	238.3	1809.7	89/09/17	3.85	220.00	216.15	7.1		3100	6.7	2920	260.0	97.0	154.0	23.0	2.10	540.0	353.0	101.0	402.0	1660

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL m	ELA m	HEAD m	FpH	FTEMP °C	FEc µS	LpH	LEc µS	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	TDS mg/l
113	F626	A	238.3	1809.7	89/10/19	2.07	220.00	217.93	7.4		3000	7.1	2920	279.0	104.0	170.0	28.0	2.20	588.0	357.0	103.0	470.0	2250
114	F626	A	238.3	1809.7	89/11/07	2.90	220.00	217.10	7.5		2800	7.3	2750	231.0	67.0	176.0	18.0	4.10	307.0	377.0	85.0	422.0	1530
115	F626	A	238.3	1809.7	89/12/19	4.36	220.00	215.64	8.0		2900	6.9	3060	326.0	93.0	171.0	19.0	1.10	540.0	439.0	127.0	466.0	1910
116	F626	A	238.3	1809.7	90/01/15	4.32	220.00	215.68	6.5		2400	7.2	2810	328.0	51.0	166.0	14.0	5.20	560.0	369.0	102.0	275.0	1580
117	F626	A	238.3	1809.7	90/02/15	5.24	220.00	214.76	6.2		2200	7.2	2920	333.0	61.0	173.0	17.0	4.30	553.0	419.0	143.0	400.0	1820
118	F626	A	238.3	1809.7	90/03/14	6.11	220.00		6.7		1800	7.2	2660	289.0	48.0	163.0	11.0	0.00	540.0	345.0	63.0	223.0	1410
119	F639	A	245.6	1822.2	89/03/10	2.79	199.00	196.21	6.8		1200	6.9	1040	136.0	30.0	54.0	1.3	0.56	567.0	73.0	28.0	0.0	612
120	F639	A	245.6	1822.2	89/04/02		199.00		7.0		1000	6.9	1050	117.0	29.0	57.0	1.0	0.45	532.0	76.0	22.0	0.0	564
121	F639	A	245.6	1822.2	89/05/02	3.02	199.00	195.98	7.0		800	6.7	1050	131.0	36.0	63.0	1.1	1.10	614.0	73.0	14.0	0.0	621
122	F639	A	245.6	1822.2	89/06/01	2.83	199.00	196.17	6.8		1000	6.9	1070	128.0	30.0	54.0	0.6	1.70	571.0	71.0	13.0	0.5	579
123	F639	A	245.6	1822.2	89/07/11	2.18	199.00	196.82	6.9	26.6	1200	6.5	1050	148.0	17.0	65.0	1.1	1.60	626.0	61.0	8.9	0.5	610
124	F639	A	245.6	1822.2	89/08/02	2.23	199.00	196.77	6.7	29.1	1200	7.0	1090	148.0	21.0	65.0	1.5	1.20	619.0	62.0	7.5	0.3	610
125	F639	A	245.6	1822.2	89/09/10	1.50	199.00	197.50	7.5	25.0	1100	7.0	1080	129.0	26.0	61.0	1.0	1.20	550.0	62.0	15.0	0.4	566
126	F639	A	245.6	1822.2	89/10/09	0.81	199.00	198.19	6.6		1400	7.0	1190	130.0	41.0	68.0	1.3	0.28	593.0	92.0	25.0	0.0	650
127	F639	A	245.6	1822.2	89/11/07	0.65	199.00	198.35	7.5		1300	7.1	1360	172.0	31.0	61.0	0.7	0.45	541.0	122.0	72.0	0.5	726
128	F639	A	245.6	1822.2	89/12/09	1.28	199.00	197.72	7.9		1100	7.1	935	110.0	16.0	70.0	0.7	0.06	383.0	93.0	49.0	0.0	527
129	F639	A	245.6	1822.2	90/01/09	2.01	199.00	196.99	7.4		1100	6.9	1200	171.0	16.0	62.0	0.6	0.75	570.0	98.0	44.0	0.0	673
130	F639	A	245.6	1822.2	90/02/06	2.02	199.00	196.98	6.7		1200	7.2	1100	134.0	21.0	58.0	0.9	0.75	493.0	85.0	41.0	0.0	583
131	F639	A	245.6	1822.2	90/03/07	2.12	199.00		6.7		900	7.0	997	124.0	15.0	59.0	0.6	5.60	453.0	85.0	22.0	0.4	529
132	F642	A	242.3	1826.2	89/03/00		200.00																
133	F642	A	242.3	1826.2	89/04/02	5.37	200.00	194.63	6.8		1100	6.9	1250	110.0	53.0	68.0	1.9	0.10	523.0	144.0	9.9	6.7	651
134	F642	A	242.3	1826.2	89/05/02	5.45	200.00	194.55	6.8		1000	6.9	1080	135.0	25.0	64.0	1.7	2.50	525.0	114.0	6.2	9.8	611
135	F642	A	242.3	1826.2	89/06/01	6.26	200.00	193.74	7.0		1100	6.9	1150	131.0	37.0	61.0	1.1	1.10	529.0	123.0	6.4	4.8	625
136	F642	A	242.3	1826.2	89/07/05	5.07	200.00	194.93	7.1	25.9	1203	6.9	1100	134.0	24.0	64.0	1.7	1.70	529.0	105.0	0.8	7.1	597
137	F642	A	242.3	1826.2	89/08/02	6.04	200.00	193.96	6.3	29.4	1400	7.0	1280	121.0	30.0	63.0	2.0	0.55	516.0	141.0	10.0	11.0	633
138	F642	A	242.3	1826.2	89/09/10	3.20	200.00	196.80	7.5	29.8	1200	7.4	862	86.0	23.0	61.0	2.3	7.80	324.0	84.0	8.1	44.0	469
139	F642	A	242.3	1826.2	89/10/09	3.67	200.00	196.33	7.7		1400	7.5	1230	131.0	27.0	70.0	2.3	1.60	502.0	139.0	13.0	7.9	637
140	F642	A	242.3	1826.2	89/11/07	3.45	200.00	196.55	7.6		1300	7.3	1410	136.0	21.0	78.0	1.5	5.90	523.0	151.0	10.0	8.6	664
141	F642	A	242.3	1826.2	89/12/09	3.58	200.00	196.42															
142	F642	A	242.3	1826.2	90/01/09	5.36	200.00	194.64	7.4		1100	7.8	1180	143.0	44.0	66.0	1.1	1.50	513.0	140.0	11.0	7.6	665
143	F642	A	242.3	1826.2	90/02/06	4.55	200.00	195.45	7.0		1000	7.1	1120	103.0	31.0	70.0	1.3	3.00	413.0	128.0	9.2	7.8	554
144	F642	A	242.3	1826.2	90/03/07	4.78	200.00		7.9		1100	7.1	1260	143.0	31.0	69.0	1.1	1.60	517.0	136.0	11.0	6.7	646
145	F672	A	262.3	1808.0	89/03/00		153.00																
146	F672	A	262.3	1808.0	89/04/10		153.00		6.7		1600	7.6	2200	202.0	75.0	124.0	5.5	0.02	517.0	359.0	20.0	182.0	1220
147	F672	A	262.3	1808.0	89/05/10		153.00		5.0		2200	7.4	2120	197.0	59.0	136.0	4.0	0.00	380.0	371.0	20.0	160.0	1130
148	F672	A	262.3	1808.0	89/06/06		153.00		7.1		2200	7.0	2440	246.0	74.0	134.0	5.9	0.00	496.0	418.0	27.0	251.0	1400
149	F672	A	262.3	1808.0	89/07/10		153.00		6.5	31.3	2400	7.4	2310	266.0	51.0	109.0	3.9	0.08	487.0	402.0	25.0	187.0	1300
150	F672	A	262.3	1808.0	89/08/09		153.00		7.1	26.6	2400	7.2	2370	273.0	48.0	130.0	5.8	0.00	518.0	388.0	25.0	184.0	1310
151	F672	A	262.3	1808.0	89/09/12		153.00		7.5		2800	7.2	2560	282.0	54.0	144.0	6.2	0.00	484.0	406.0	29.0	216.0	1380
152	F672	A	262.3	1808.0	89/10/18		153.00		7.4		2600	7.0	2410	278.0	56.0	135.0	4.0	0.05	494.0	409.0	23.0	139.0	1290
153	F672	A	262.3	1808.0	89/11/03		153.00		7.4		2400	7.9	2280	269.0	55.0	128.0	4.3	0.00	514.0	387.0	26.0	365.0	1490
154	F672	A	262.3	1808.0	89/12/13		153.00		7.5		2300	7.6	2430	269.0	53.0	137.0	4.1	0.00	506.0	404.0	29.0	230.0	1380
155	F672	A	262.3	1808.0	90/01/17		153.00		6.9		2000	7.7	2230	229.0	46.0	133.0	3.2	0.00	386.0	381.0	27.0	125.0	1130
156	F672	A	262.3	1808.0	90/02/16		153.00		7.3		2500	7.4	2320	267.0	44.0	129.0	3.2	0.00	511.0	369.0	30.0	138.0	1230
157	F672	A	262.3	1808.0	90/03/14		153.00		7.3		1800	7.6	2240	258.0	50.0	131.0	3.6	0.00	525.0	353.0	28.0	204.0	1290
158	F716	A	257.3	1816.4	89/03/11	7.33	161.00	153.67	7.0		4200	6.8	3680	316.0	75.0	318.0	4.8	3.70	386.0	1010.0	4.8	39.0	1960
159	F716	A	257.3	1816.4	89/04/10	9.19	161.00	151.81	6.8		3200	7.4	3650	253.0	70.0	340.0	4.4	0.74	169.0	1040.0	3.9	21.0	1820
160	F716	A	257.3	1816.4	89/05/10	6.98	161.00	154.02	6.8		3600	6.9	4000	352.0	90.0	290.0	3.2	1.10	406.0	1080.0	3.1	41.0	2060
161	F716	A	257.3	1816.4	89/06/09	7.09	161.00	153.91	6.4		3100	7.3	3560	256.0	66.0	295.0	3.9	3.40	97.0	1050.0	2.9	29.0	1750
162	F716	A	257.3	1816.4	89/07/11	6.88	161.00	154.12	6.5	30.2	4800	6.9	3990	404.0	57.0	290.0	3.9	2.60	403.0	1110.0	3.4	38.0	2100
163	F716	A	257.3	1816.4	89/08/10	7.34	161.00	153.66	4.3	31.2	4100	7.4	3800	275.0	77.0	283.0	3.8	1.70	310.0	1040.0	9.7	26.0	1870
164	F716	A	257.3	1816.4	89/09/09	6.90	161.00	154.10	7.1	29.5	4500	6.8	4110	376.0	78.0	314.0	4.0	0.94	390.0	1070.0	3.3	48.0	2090
165	F716	A	257.3	1816.4	89/10/18	5.60	161.00	155.40	7.3		5300	7.0	4840	408.0	118.0	372.0	4.2	2.30	405.0	1320.0	4.3	127.0	2560
166	F716	A	257.3	1816.4	89/11/03	5.00	161.00	156.00	7.4		4500	7.4	4540	386.0	87.0	317.0	2.9	1.90	416.0	1150.0	3.0	28.0	2180
167	F716	A	257.3	1816.4	89/12/19	4.87	161.00	156.13	8.1		3900	7.0	4210	429.0	68.0	338.0	3.1	2.60	406.0	1130.0	3.0	52.0	2220
168	F716	A	257.3	1816.4	90/01/16	9.72	161.00	151.28	6.4		3300	7.0	5260	774.0	158.0	365.0	2.2	1.40	415.0	2260.0	3.9	54.0	3820

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
169	F716	A	257.3	1816.4	90/02/16	6.80	161.00	154.20	6.9		2900	7.3	3830	321.0	78.0	288.0	2.6	0.99	281.0	1060.0	3.0	30.0	1920
170	F716	A	257.3	1816.4	90/03/14	6.85	161.00		7.1		3100	6.9	4100	374.0	84.0	310.0	2.1	0.00	413.0	1080.0	2.2	21.0	2070
171	F859	A	256.5	1811.3	89/03/00		157.76																
172	F859	A	256.5	1811.3	89/04/10	3.27	157.76	154.49	6.8		3100	8.0	3590	110.0	21.0	590.0	2.8	1.60	173.0	1020.0	29.0	0.4	1850
173	F859	A	256.5	1811.3	89/05/10	3.35	157.76	154.41	7.1		3500	7.4	3750	127.0	21.0	610.0	1.8	0.90	286.0	1040.0	28.0	0.0	1970
174	F859	A	256.5	1811.3	89/06/06		157.76		7.1		3200	7.3	3690	138.0	20.0	590.0	2.1	1.20	277.0	1010.0	33.0	2.6	1930
175	F859	A	256.5	1811.3	89/07/11	3.13	157.76	154.63	7.7	30.7	4200	7.2	3760	132.0	17.0	570.0	2.1	1.10	283.0	1040.0	36.0	1.1	1940
176	F859	A	256.5	1811.3	89/08/09		157.76		8.7	25.4	3500	7.4	3800	111.0	24.0	561.0	2.1	0.10	283.0	1030.0	32.0	1.2	1900
177	F859	A	256.5	1811.3	89/09/12		157.76		7.8		4200	7.2	3780	138.0	14.0	602.0	1.9	4.30	263.0	1040.0	32.0	1.1	1960
178	F859	A	256.5	1811.3	89/10/18	2.61	157.76	155.15	7.2		3900	7.4	3600	116.0	26.0	573.0	2.8	4.80	247.0	967.0	24.0	0.4	2250
179	F859	A	256.5	1811.3	89/11/03	2.45	157.76	155.31	7.4		4000	7.6	3960	146.0	15.0	584.0	1.9	3.00	255.0	1020.0	33.0	0.0	1890
180	F859	A	256.5	1811.3	89/12/12	2.46	157.76	155.30	7.6		3600	7.2	3740	134.0	23.0	555.0	2.2	7.30	256.0	1020.0	33.0	0.0	1890
181	F859	A	256.5	1811.3	90/01/18	3.08	157.76	154.68	6.9		5000	7.4	6650	158.0	29.0	1140.0	6.3	14.00	227.0	1970.0	53.0	0.5	3470
182	F859	A	256.5	1811.3	90/02/16	3.25	157.76	154.51	6.5		3000	7.6	3620	118.0	30.0	557.0	1.7	17.00	267.0	1040.0	28.0	0.6	1900
183	F859	A	256.5	1811.3	90/03/14	3.26	157.76		7.0		3100	7.3	3840	122.0	23.0	605.0	1.2	0.00	258.0	1020.0	32.0	0.4	1930
184	F861	A	250.5	1829.4	89/03/00		195.00																
185	F861	A	250.5	1829.4	89/04/02	7.23	195.00	187.77	7.2		1200	7.5	1360	80.0	11.0	214.0	2.2	1.40	299.0	50.0	425.0	0.2	929
186	F861	A	250.5	1829.4	89/05/02	8.50	195.00	186.50	6.7		1500	7.3	1300	81.0	14.0	212.0	1.9	1.60	310.0	59.0	315.0	0.0	836
187	F861	A	250.5	1829.4	89/06/01	7.60	195.00	187.40	7.2		1300	7.3	1330	33.0	37.0	220.0	1.2	3.40	318.0	56.0	384.0	0.3	880
188	F861	A	250.5	1829.4	89/07/05	6.32	195.00	188.68	7.7	23.7	1400	7.5	1350	74.0	11.0	206.0	2.0	3.70	318.0	50.0	444.0	0.6	954
189	F861	A	250.5	1829.4	89/08/02	5.34	195.00	189.66	7.7	31.5	1600	7.4	1470	91.0	7.6	193.0	2.1	5.90	292.0	58.0	368.0	0.0	864
190	F861	A	250.5	1829.4	89/09/10		195.00		7.8	30.4	1600	7.4	1370	86.0	12.0	210.0	2.4	3.40	321.0	59.0	410.0	0.7	938
191	F861	A	250.5	1829.4	89/10/09		195.00		7.4		1600	7.7	1400	85.0	16.0	205.0	2.4	2.10	313.0	58.0	367.0	0.3	889
192	F861	A	250.5	1829.4	89/11/07	5.07	195.00	189.93	7.5		1400	7.8	1470	103.0	2.6	213.0	1.5	1.10	309.0	56.0	360.0	0.0	889
193	F861	A	250.5	1829.4	89/12/09	4.50	195.00	190.50	7.6		1400	8.2	1430	85.0	9.4	203.0	2.0	2.30	298.0	60.0	381.0	0.0	886
194	F861	A	250.5	1829.4	90/01/16	5.02	195.00	189.98	6.7		1300	7.4	1490	85.0	15.0	194.0	1.1	0.88	301.0	60.0	389.0	0.0	891
195	F861	A	250.5	1829.4	90/02/06	5.11	195.00	189.89	6.6		1100	8.3	1390	85.0	8.5	223.0	1.4	5.00	276.0	44.0	387.0	0.2	896
196	F861	A	250.5	1829.4	90/03/07	6.15	195.00		7.2		1200	8.1	1420	86.0		215.0	1.3	1.20	299.0	63.0	397.0	0.3	923
197	L794	A	258.7	1825.3	89/03/11	7.81	178.00	170.19	6.9		12100	7.8	10200	288.0	204.0	2160.0	2.9	3.00	520.0	3870.0	313.0	0.5	7100
198	L794	A	258.7	1825.3	89/04/09	8.15	178.00	169.85	6.5		7700	7.1	11800	344.0	146.0	2100.0	2.9	3.70	524.0	3790.0	315.0	1.0	6960
199	L794	A	258.7	1825.3	89/05/09	8.15	178.00	169.85	6.6		1200	7.0	11600	328.0	141.0	2030.0	2.0	20.00	584.0	3720.0	277.0	0.0	6780
200	L794	A	258.7	1825.3	89/06/09	8.21	178.00	169.79	6.7		8400	6.9	11700	432.0	90.0	1880.0	2.4	18.00	485.0	3610.0	284.0	4.2	6540
201	L794	A	258.7	1825.3	89/07/11	7.79	178.00	170.21	6.5		11200	7.8	11500	340.0	182.0	2050.0	2.5	18.00	473.0	3560.0	285.0	0.0	6650
202	L794	A	258.7	1825.3	89/08/09	8.81	178.00	169.19	7.5		11500	7.0	11900	360.0	163.0	1870.0	2.9	8.30	479.0	3640.0	283.0	4.4	6560
203	L794	A	258.7	1825.3	89/09/09	7.90	178.00	170.10	6.8		12700	7.1	11700	420.0	100.0	2030.0	2.4	4.00	516.0	3570.0	291.0	2.5	6670
204	L794	A	258.7	1825.3	89/10/19	7.95	178.00	170.05	7.1		11100	7.0	11900	328.0	165.0	1970.0	2.7	8.60	519.0	3710.0	280.0	0.7	6710
205	L794	A	258.7	1825.3	89/11/03	7.80	178.00	170.20	7.3		10900	7.0	12500	368.0	170.0	2050.0	1.8	29.00	586.0	3650.0	296.0	0.5	6820
206	L794	A	258.7	1825.3	89/12/13	7.88	178.00	170.12	7.3		11200	7.3	11700	448.0	175.0	2080.0	2.6	12.00	512.0	3780.0	299.0	0.5	7030
207	L794	A	258.7	1825.3	90/01/15	7.83	178.00	170.17	6.7		8700	7.7	12200	248.0	302.0	2020.0	1.3	1.50	589.0	3710.0	290.0	0.4	6860
208	L794	A	258.7	1825.3	90/02/15	7.94	178.00	170.06	6.6		7600	7.9	11200	280.0	272.0	1970.0	1.8	9.50	460.0	3600.0	312.0	0.3	6660
209	L794	A	258.7	1825.3	90/03/14	7.85	178.00		6.7		7500	6.9	11900	328.0	156.0	2110.0	1.8	0.00	542.0	3590.0	320.0	0.7	6770
210	P01	A	240.2	1823.5	89/03/00		208.00																
211	P01	A	240.2	1823.5	89/04/02	7.64	208.00	200.36															
212	P01	A	240.2	1823.5	89/05/02	8.08	208.00	199.92	6.9		500	6.9	694	89.0	21.0	47.0	2.5	2.10	470.0	13.0	4.5	0.0	408
213	P01	A	240.2	1823.5	89/06/01	7.09	208.00	200.91	7.0		600	7.7	354	27.0	8.9	35.0	1.9	0.00	172.0	17.0	17.0	1.0	178
214	P01	A	240.2	1823.5	89/07/11	5.59	208.00	202.41	7.2		700	7.0	733	84.0	4.4	43.0	3.5	8.40	388.0	11.0	5.5	0.8	343
215	P01	A	240.2	1823.5	89/08/02	6.16	208.00	201.84	6.5		800	7.3	754	98.0	14.0	41.0	2.8	0.69	476.0	13.0	8.3	0.5	412
216	P01	A	240.2	1823.5	89/09/12	3.32	208.00	204.68	7.4		200	5.6	215	15.0	1.9	17.0	0.8	0.26	27.0	45.0	0.6	0.3	94
217	P01	A	240.2	1823.5	89/10/09	2.55	208.00	205.45	6.6		200	6.0	202	17.0	8.7	9.8	0.7	0.00	31.0	47.0	0.6	0.0	98
218	P01	A	240.2	1823.5	89/11/14	3.88	208.00	204.12	7.2		400	6.2	378	52.0	8.3	13.0	1.2	0.41	139.0	60.0	0.0	0.0	202
219	P01	A	240.2	1823.5	89/12/09	3.92	208.00	204.08	7.8		300	6.7	348	47.0	6.3	11.0	0.6	0.30	147.0	39.0	3.4	0.0	179
220	P01	A	240.2	1823.5	90/01/09	6.22	208.00	201.78	7.2		500	7.8	538	89.0	6.6	12.0	0.8	1.10	279.0	36.0	0.0	3.0	285
221	P01	A	240.2	1823.5	90/02/06	7.22	208.00	200.78	6.9		700	8.1	644	92.0	7.5	22.0	1.2	3.60	305.0	51.0	0.6	1.3	326
222	P01	A	240.2	1823.5	90/03/07	6.90	208.00		6.7		600	6.8	605	94.0	7.4	17.0	0.7	0.56	329.0	28.0	1.1	0.0	311
223	P11	A	267.7	1823.0	89/03/00		199.28																
224	P11	A	267.7	1823.0	89/04/08	17.48	199.28	181.80															

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS
						m	m	m		° C	μS		μS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
225	P11	A	267.7	1823.0	89/05/11	18.15	199.28	181.13	6.2		1130	6.9	968	51.0	49.0	50.0	2.7	4.00	299.0	62.0	73.0	9.4	444
226	P11	A	267.7	1823.0	89/06/09	18.10	199.28	181.18	6.8		700	6.8	762	52.0	44.0	40.0	2.4	3.00	299.0	49.0	91.0	11.0	437
227	P11	A	267.7	1823.0	89/07/12	17.64	199.28	181.64	6.6		900	6.7	688	44.0	31.0	46.0	3.6	1.60	277.0	68.0	33.0	0.7	363
228	P11	A	267.7	1823.0	89/08/11	17.90	199.28	181.38	7.0		800	6.6	738	47.0	33.0	55.0	3.7	2.10	276.0	80.0	51.0	2.3	406
229	P11	A	267.7	1823.0	89/09/17	17.68	199.28	181.60	7.2		800	6.8	771	50.0	33.0	58.0	3.7	0.90	259.0	79.0	41.0	1.6	394
230	P11	A	267.7	1823.0	89/10/10	17.51	199.28	181.77	6.9		900	8.2	750	46.0	38.0	57.0	2.5	0.30	280.0	79.0	55.0	3.1	418
231	P11	A	267.7	1823.0	89/11/17	17.29	199.28	181.99	7.7		900	8.0	828	56.0	45.0	48.0	3.1	0.64	302.0	82.0	86.0	14.0	483
232	P11	A	267.7	1823.0	89/12/11	17.15	199.28	182.13	8.0		900	7.1	915	57.0	45.0	53.0	3.2	0.75	304.0	80.0	72.0	7.6	469
233	P11	A	267.7	1823.0	90/01/15	17.18	199.28	182.10	7.0		800	7.1	1020	71.0	46.0	60.0	2.2	0.50	345.0	101.0	82.0	8.0	541
234	P11	A	267.7	1823.0	90/02/17	17.26	199.28	182.02	7.0		900	8.0	950	60.0	45.0	63.0	3.3	5.30	306.0	100.0	86.0	12.0	519
235	P11	A	267.7	1823.0	90/03/08	17.50	199.28		6.9		700	6.9	879	58.0	43.0	51.0	2.8	0.72	301.0	84.0	87.0	10.0	484
236	P12	A	266.7	1823.1	89/03/08		199.28																
237	P12	A	266.7	1823.1	89/04/08	16.59	199.28	182.69															
238	P12	A	266.7	1823.1	89/05/11	17.48	199.28	181.80	6.4		680	6.9	686	71.0	43.0	13.0	6.4	6.30	432.0	13.0	20.0	0.0	379
239	P12	A	266.7	1823.1	89/06/09	17.46	199.28	181.82	6.6		500	6.8	513	54.0	28.0	8.9	5.0	1.30	322.0	7.1	9.7	0.2	271
240	P12	A	266.7	1823.1	89/07/12	17.38	199.28	181.90	6.6		500	6.4	452	45.0	24.0	11.0	5.4	0.56	267.0	13.0	1.2	1.6	233
241	P12	A	266.7	1823.1	89/08/11	18.44	199.28	180.84	6.9		500	6.5	437	43.0	24.0	10.0	5.3	0.84	272.0	8.7	2.1	0.3	227
242	P12	A	266.7	1823.1	89/09/16	17.59	199.28	181.69	7.0		500	6.4	448	43.0	24.0	10.0	5.7	0.59	250.0	7.8	2.1	0.0	215
243	P12	A	266.7	1823.1	89/10/10	17.09	199.28	182.19	7.0		500	8.1	415	40.0	26.0	11.0	3.8	0.34	274.0	9.3	2.6	0.0	227
244	P12	A	266.7	1823.1	89/11/17	16.54	199.28	182.74	7.9		200	6.8	257	21.0	13.0	12.0	4.5	0.26	152.0	5.1	0.0	3.4	133
245	P12	A	266.7	1823.1	89/12/11	16.06	199.28	183.22	7.9		200	6.1	253	19.0	12.0	10.0	7.8	0.50	137.0	9.8	0.0	4.8	131
246	P12	A	266.7	1823.1	90/01/15	16.09	199.28	183.19	6.9		200	8.0	321	38.0	8.6	9.9	4.0	0.53	179.0	6.6	0.0	4.3	159
247	P12	A	266.7	1823.1	90/02/17	16.18	199.28	183.10	7.0		200	7.1	210	17.0	7.9	10.0	5.7	1.60	118.0	8.3	0.3	3.7	112
248	P12	A	266.7	1823.1	90/03/08	16.81	199.28		6.8		200	7.3	211	15.0	8.9	9.6	4.3	0.61	116.0	4.0	0.0	2.5	102
249	P13	A	266.9	1821.4	89/03/00		186.86																
250	P13	A	266.9	1821.4	89/04/00		286.86																
251	P13	A	266.9	1821.4	89/05/00		186.86																
252	P13	A	266.9	1821.4	89/06/09	7.71	186.86	179.15	6.9		600	6.7	613	42.0	15.0	57.0	1.8	0.53	186.0	88.0	32.0	0.3	328
253	P13	A	266.9	1821.4	89/07/12	7.86	186.86	179.00	7.5	29.5	600	7.6	479	15.0	12.0	35.0	1.8	0.30	187.0	50.0	23.0	0.7	260
254	P13	A	266.9	1821.4	89/08/10	7.60	186.86	179.26	7.2	26.7	600	7.0	561	40.0	19.0	41.0	2.1	0.46	210.0	65.0	23.0	0.3	294
255	P13	A	266.9	1821.4	89/09/17	6.56	186.86	180.30	6.8		100	6.9	533	45.0	16.0	37.0	2.2	0.13	194.0	48.0	21.0	0.3	264
256	P13	A	266.9	1821.4	89/10/10	6.36	186.86	180.50	6.8		500	6.8	492	44.0	17.0	33.0	1.5	0.57	211.0	46.0	17.0	0.5	262
257	P13	A	266.9	1821.4	89/11/17	6.84	186.86	180.02	7.2		500	7.0	500	45.0	16.0	39.0	1.8	0.11	213.0	54.0	17.0	0.0	276
258	P13	A	266.9	1821.4	89/12/11	6.86	186.86	180.00	7.9		500	7.1	511	43.0	20.0	35.0	1.8	0.00	213.0	53.0	16.0	0.0	273
259	P13	A	266.9	1821.4	90/01/15	7.18	186.86	179.68	7.0		400	6.9	542	47.0	11.0	39.0	1.3	0.31	212.0	51.0	13.0	0.0	266
260	P13	A	266.9	1821.4	90/02/17	7.27	186.86	179.59	7.1		400	7.9	518	44.0	13.0	35.0	1.6	0.78	202.0	52.0	21.0	0.2	267
261	P13	A	266.9	1821.4	90/03/08	7.57	186.86		7.0		400	7.0	504	45.0	14.0	34.0	1.5	0.57	213.0	47.0	8.0	0.0	254
262	P14	A			89/03/00		0.00																
263	P14	A			89/04/08	7.60	0.00																
264	P14	A			89/05/11	7.38			6.2		160	5.9	176	8.8	4.7	16.0	2.4	2.20	64.0	18.0	4.0	0.0	86
265	P14	A			89/06/09	7.25			6.5		200	6.4	149	11.0	1.2	16.0	2.2	0.55	54.0	16.0	10.0	0.8	84
266	P14	A			89/07/12	6.69			7.1	29.3	100	7.3	130	7.8	3.6	11.0	2.3	0.27	43.0	14.0	8.9	1.6	70
267	P14	A			89/08/10	7.78			7.4	27.9	600	7.0	5180	8.3	2.8	15.0	2.5	0.46	41.0	19.0	9.9	1.7	79
268	P14	A			89/09/17	7.53			7.5		500	5.4	153	9.9	1.8	14.0	2.5	0.13	38.0	14.0	8.0	1.5	70
269	P14	A			89/10/10	7.33			6.1		100	7.2	132	7.4	3.4	12.0	1.6	0.30	42.0	13.0	8.5	1.9	69
270	P14	A			89/11/17	5.94			6.9		100	6.8	150	10.0	3.6	12.0	2.0	0.03	21.0	27.0	8.2	4.7	78
271	P14	A			89/12/11	6.06			7.9		100	6.8	147	6.2	6.9	12.0	2.9	0.08	37.0	20.0	8.9	5.4	80
272	P14	A			90/01/15	6.49			6.7		100	8.2	378	58.0	3.8	12.0	1.7	0.22	190.0	17.0	6.4	4.3	197
273	P14	A			90/02/17	6.68			7.1		100	6.8	150	8.3	3.8	14.0	1.6	0.56	40.0	19.0	8.6	4.9	80
274	P14	A			90/03/08	6.56			7.1		100	6.4	156	7.2	5.6	13.0	1.6	0.67	41.0	16.0	8.0	3.5	75
275	P15	A	266.6	1819.1	89/03/00		160.73																
276	P15	A	266.6	1819.1	89/04/08	2.20	160.73	158.53															
277	P15	A	266.6	1819.1	89/05/09	2.03	160.73	158.70	6.8		19900	6.5	70200	520.0	340.0	1920.0	86.0	5.00	331.0	29700.0	890.0	7.4	50800
278	P15	A	266.6	1819.1	89/06/09	2.13	160.73	158.60	6.5		19900	6.7	71200	740.0	97.0	2280.0	37.0	0.83	323.0	28200.0	1020.0	14.0	53100
279	P15	A	266.6	1819.1	89/07/12	1.75	160.73	158.98	6.5	29.1	19900	6.6	68500	632.0	161.0	1780.0	81.0	1.10	317.0	27800.0	1010.0	46.0	47700
280	P15	A	266.6	1819.1	89/08/10	1.94	160.73	158.79	7.2	27.7	19900	6.9	58000	720.0	97.0	1390.0	0.0	76.00	0.0	345.0	22500.0	651.0	35

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS
						m	m	m		° C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
281	P15	A	266.6	1819.1	89/09/17	1.75	160.73	158.98	6.5		19900	7.1	71000	500.0	231.0	17880.0	83.0	1.50	359.0	27000.0	865.0	30.0	46800
282	P15	A	266.6	1819.1	89/10/10	1.66	160.73	159.07	6.7		19900	6.8	56600	400.0	165.0	14100.0	67.0	0.79	341.0	22000.0	622.0	0.0	37600
283	P15	A	266.6	1819.1	89/11/17	1.85	160.73	158.88	7.2		19900	6.9	65000	544.0	122.0	16000.0	91.0	0.55	309.0	26000.0	871.0	0.0	43800
284	P15	A	266.6	1819.1	89/12/00		160.73																
285	P15	A	266.6	1819.1	90/01/15	1.49	160.73	159.24	6.9		19900	7.0	71100	520.0	214.0	17100.0	84.0	0.88	319.0	28600.0	930.0	0.3	47600
286	P15	A	266.6	1819.1	90/02/17	2.08	160.73	158.65	7.1		19900	7.0	61600	432.0	175.0	1560.0	52.0	2.10	310.0	24300.0	860.0	0.5	41500
287	P15	A	266.6	1819.1	90/03/08	2.16	160.73		6.9		19900	7.0	55000	376.0	204.0	1460.0	53.0	0.52	262.0	21400.0	732.0	0.3	35700
288	P16	A	266.6	1819.1	89/03/00		160.82																
289	P16	A	266.6	1819.1	89/04/08	1.40	160.82	159.42															
290	P16	A	266.6	1819.1	89/05/09	1.50	160.82	159.32															
291	P16	A	266.6	1819.1	89/06/09	1.07	160.82	159.75	6.8		3900	6.8	4280	179.0	49.0	660.0	1.8	5.50	371.0	1050.0	244.0	0.8	2370
292	P16	A	266.6	1819.1	89/07/12	1.01	160.82	159.81	6.5		4600	6.9	3630	176.0	51.0	522.0	1.8	0.56	350.0	909.0	236.0	0.8	2070
293	P16	A	266.6	1819.1	89/08/10	0.82	160.82	160.00	8.6		3900	6.6	3860	220.0	18.0	549.0	4.1	1.50	344.0	970.0	206.0	0.8	2140
294	P16	A	266.6	1819.1	89/09/17	1.00	160.82	159.82	7.0		5200	6.9	3820	166.0	48.0	542.0	3.8	0.44	338.0	887.0	208.0	0.7	2020
295	P16	A	266.6	1819.1	89/10/10	0.99	160.82	159.83	6.5		3800	8.2	3470	150.0	75.0	510.0	8.7	0.36	331.0	837.0	179.0	27.0	1950
296	P16	A	266.6	1819.1	89/11/17	1.35	160.82	159.47	7.5		3800	7.9	3760	166.0	69.0	540.0	3.2	0.22	356.0	935.0	227.0	11.0	2130
297	P16	A	266.6	1819.1	89/12/00		160.82																
298	P16	A	266.6	1819.1	90/01/15	1.62	160.82	159.20	6.4		4000	8.2	4420	174.0	41.0	78.0	2.8	0.22	368.0	1120.0	190.0	9.6	2980
299	P16	A	266.6	1819.1	90/02/17	1.32	160.82	159.50	6.5		3200	6.9	4030	180.0	51.0	552.0	1.2	0.76	357.0	995.0	259.0	1.3	2220
300	P16	A	266.6	1819.1	90/03/08	1.29	160.82		6.8		3000	6.9	3810	183.0	48.0	540.0	9.7	0.29	352.0	909.0	266.0	0.8	2120
301	P17	A	265.6	1819.6	89/03/00		155.55																
302	P17	A	265.6	1819.6	89/04/08	2.55	255.55	253.00															
303	P17	A	265.6	1819.6	89/05/11	3.28	255.55	252.27	7.1		19900	6.9	10600	88.0	20.0	2350.0	11.0	0.25	132.0	3680.0	21.0	0.5	6230
304	P17	A	265.6	1819.6	89/06/09	3.20	155.55	152.35	7.0		8500	6.9	11100	112.0	34.0	2470.0	10.0	0.37	140.0	3620.0	42.0	1.1	6350
305	P17	A	265.6	1819.6	89/07/09	2.69	155.55	152.86	7.8	25.8	11100	6.9	10700	176.0	0.0	2040.0	11.0	0.46	140.0	3680.0	19.0	12.0	6000
306	P17	A	265.6	1819.6	89/08/07	2.56	155.55	152.99	8.0	28.3	10900	7.0	10900	24.0	73.0	2140.0	11.0	0.56	140.0	3720.0	19.0	2.5	6030
307	P17	A	265.9	1819.6	89/09/16	1.49	255.55	254.06	7.9		10500	7.1	11100	91.0	11.0	2410.0	11.0	0.93	119.0	3560.0	24.0	1.5	6160
308	P17	A	265.9	1819.6	89/10/19	1.08	255.55	254.47	7.4		9700	6.8	10300	80.0	87.0	2090.0	7.6	0.65	125.0	3570.0	22.0	0.0	5910
309	P17	A	265.6	1819.6	89/11/18	1.07	155.55	154.48	7.1		10800	7.6	10600	90.0	67.0	2220.0	10.0	0.66	119.0	3600.0	25.0	2.5	6070
310	P17	A	265.6	1819.6	89/12/00		255.55																
311	P17	A	265.6	1819.6	90/01/15	2.16	155.55	153.39	6.8		8800	7.2	11300	85.0	25.0	2130.0	6.1	0.77	121.0	3580.0	30.0	1.8	5920
312	P17	A	265.6	1819.6	90/02/16	2.58	155.55	152.97	7.1		8100	7.3	10300	73.0	21.0	2150.0	8.3	1.80	123.0	3430.0	27.0	0.4	5760
313	P17	A	265.6	1819.6	90/03/08	2.83	255.55		7.0		7500	7.2	10500	84.0	36.0	2100.0	6.0	0.52	133.0	3360.0	24.0	1.0	5680
314	P18	A	265.6	1819.1	89/03/00		155.47																
315	P18	A	265.6	1819.1	89/04/08	2.57	155.47	152.90															
316	P18	A	265.6	1819.1	89/05/11	3.22	155.47	152.25	6.6		1990	7.1	5240	86.0	18.0	1060.0	3.2	3.70	380.0	1580.0	1.5	0.0	2940
317	P18	A	265.6	1819.1	89/06/09	3.19	155.47	152.28	7.0		3800	7.2	4550	60.0	11.0	910.0	2.5	2.40	349.0	1250.0	20.0	0.7	2430
318	P18	A	265.6	1819.1	89/07/09	2.46	155.47	153.01	6.2	26.6	4000	7.2	3730	42.0	6.3	728.0	2.6	0.52	328.0	1020.0	7.8	2.4	1970
319	P18	A	265.6	1819.1	89/08/07	2.57	155.47	152.90	8.4	29.3	3900	7.2	3880	46.0	6.8	736.0	2.8	0.08	328.0	1060.0	8.8	1.6	2020
320	P18	A	265.6	1819.1	89/09/16	1.47	155.47	154.00	7.8		4000	7.2	3880	51.0	28.0	762.0	2.8	0.14	306.0	1060.0	8.6	1.2	2070
321	P18	A	265.6	1819.1	89/10/19	0.94	155.47	154.53	7.6		3900	7.1	3730	37.0	11.0	743.0	12.9	0.22	324.0	1040.0	9.9	0.0	2000
322	P18	A	265.6	1819.1	89/11/18	1.50	155.47	153.97	7.1		4200	7.7	3970	44.0	8.3	780.0	2.3	0.25	325.0	1120.0	17.0	2.5	2130
323	P18	A	265.6	1819.1	89/12/00		155.47																
324	P18	A	265.6	1819.1	90/01/15	2.06	155.47	153.41	6.6		3500	7.5	3930	42.0	12.0	800.0	2.2	1.10	323.0	1120.0	28.0	1.3	2160
325	P18	A	265.6	1819.1	90/02/16	2.55	155.47	152.92	6.6		3100	7.6	3540	32.0	6.3	672.0	1.9	2.60	230.0	960.0	26.0	0.7	1810
326	P18	A	265.6	1819.1	90/03/08	2.75	155.47		7.1		2700	7.5	3570	26.0	8.8	669.0	1.3	0.52	247.0	949.0	22.0	0.6	1800
327	P19	A	263.2	1814.4	89/03/00		155.79																
328	P19	A	263.2	1814.4	89/04/00	1.85	155.79	153.94															
329	P19	A	263.2	1814.4	89/05/11	2.52	155.79	153.27	7.5		1020	7.3	1220	11.0	0.8	273.0	1.7	0.50	299.0	255.0	1.1	0.0	690
330	P19	A	263.2	1814.4	89/05/24	2.60	155.79	153.19	8.8		1200	7.1	1280	13.0	2.4	250.0	1.6	1.80	308.0	252.0	0.7	0.6	671
331	P19	A	263.2	1814.4	89/06/09	2.50	155.79	153.29	7.4		1200	7.2	1320	14.0	1.3	270.0	1.7	0.42	305.0	261.0	1.3	0.7	701
332	P19	A	263.2	1814.4	89/07/09	1.53	155.79	154.26	6.3	29.0	1500	7.1	1310	17.0	1.5	245.0	2.2	0.77	313.0	274.0	1.5	1.0	696
333	P19	A	263.2	1814.4	89/08/07	1.75	155.79	154.04	8.4	30.8	1400	6.9	1320	19.0	0.0	256.0	2.3	0.89	315.0	262.0	1.2	0.5	696
334	P19	A	263.2	1814.4	89/09/17	1.13	155.79	154.66	7.8		1500	7.0	1380	21.0	0.8	266.0	2.7	0.81	301.0	260.0	0.8	0.5	700
335	P19	A	263.2	1814.4	89/10/19	0.78	155.79	155.01	7.9		1300	7.1	1220	14.0	2.9	239.0	1.2	0.70	301.0	247.0	0.3	0.0	652
336	P19	A	263.2	1814.4	89/11/18	0.80	155.79	154.99	7.9		1500	7.3	1350	18.0	15.0	259.0	1.6	0.50	320.0	273.0	0.0	0.5	725

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL	SUB-	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS
	NO.	BASIN				m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
337	P19	A	263.2	1814.4	89/12/00		155.79																
338	P19	A	263.2	1814.4	90/01/15	1.63	155.79	154.16	6.4		1200	9.1	1310	13.0	0.3	282.0	1.8	1.30	220.0	273.0	0.5	0.0	696
339	P19	A	263.2	1814.4	90/02/16	2.02	155.79	153.77	6.9		1200	7.7	1392	21.0	0.9	267.0	2.0	1.10	321.0	277.0	0.0	0.8	728
340	P19	A	263.2	1814.4	90/03/08	2.24	155.79		7.0		1300	7.4	1360	17.0	2.1	256.0	1.4	1.20	323.0	262.0	0.0	0.3	698
341	P20	A	243.2	1814.4	89/03/00		155.74																
342	P20	A	243.2	1814.4	89/04/08	2.39	155.74	153.35															
343	P20	A	243.2	1814.4	89/05/11	2.90	155.74	152.84	7.6		1010	7.7	898	9.9	1.7	206.0	1.1	3.00	308.0	145.0	3.4	0.0	519
344	P20	A	243.2	1814.4	89/06/09	2.68	155.74	153.06	7.5		1100	7.6	1130	18.0	0.3	235.0	1.2	2.30	295.0	203.0	1.3	0.2	604
345	P20	A	243.2	1814.4	89/07/09	2.21	155.74	153.53	6.3	27.7	1200	7.4	1060	13.0	2.1	202.0	1.3	0.44	295.0	191.0	0.4	1.0	556
346	P20	A	243.2	1814.4	89/08/07	1.83	155.74	153.91	8.6	29.6	1200	7.8	1070	14.0	1.2	202.0	1.3	0.26	290.0	196.0	0.0	0.0	557
347	P20	A	243.2	1814.4	89/09/16	1.08	155.74	154.66	8.0		1200	7.6	1090	12.0	1.0	214.0	1.2	0.30	268.0	188.0	0.6	0.3	548
348	P20	A	243.2	1814.4	89/10/19	0.94	155.74	154.80	8.1		1100	7.6	1010	8.8	3.9	199.0	0.7	0.00	286.0	188.0	1.4	0.0	542
349	P20	A	243.2	1814.4	89/11/18	1.12	155.74	154.62	8.1		1100	8.0	1030	14.0	0.3	235.0	0.9	0.00	285.0	203.0	0.0	0.9	573
350	P20	A	243.2	1814.4	89/12/00		155.74																
351	P20	A	243.2	1814.4	90/01/15	2.21	155.74	153.53	6.9		1000	7.7	1130	15.0	4.4	214.0	1.1	0.66	304.0	204.0	0.5	0.4	590
352	P20	A	243.2	1814.4	90/02/16	2.56	155.74	153.18	6.8		1000	7.7	1110	11.0	2.9	212.0	1.0	0.89	288.0	205.0	0.6	1.5	576
353	P20	A	243.2	1814.4	90/03/08	2.73	155.74		6.9		1100	7.5	1200	12.0	2.4	221.0	1.0	0.17	289.0	218.0	1.3	2.0	600
354	P22	A	254.7	1821.9	89/03/00		181.00																
355	P22	A	254.7	1821.9	89/04/00	9.94	181.00	171.06															
356	P22	A	254.7	1821.9	89/05/02		181.00		6.4		1500	7.4	1490	101.0	30.0	156.0	1.8	0.16	419.0	188.0	6.3	109.0	798
357	P22	A	254.7	1821.9	89/06/01		181.00		6.5		1400	7.2	1470	122.0	19.0	156.0	1.5	0.00	423.0	185.0	4.3	104.0	799
358	P22	A	254.7	1821.9	89/07/11		181.00		6.5		1600	7.2	1430	130.0	9.7	150.0	2.1	0.00	415.0	183.0	6.0	127.0	812
359	P22	A	254.7	1821.9	89/08/02	8.74	181.00	172.26	6.6		1600	7.3	1410	108.0	27.0	141.0	2.1	0.00	422.0	175.0	2.8	79.0	742
360	P22	A	254.7	1821.9	89/09/10		181.00		8.0		1400	7.3	1380	119.0	19.0	136.0	1.9	0.04	396.0	169.0	4.7	48.0	692
361	P22	A	254.7	1821.9	89/10/09		181.00		6.9		1400	7.4	1280	82.0	2.9	141.0	1.9	0.03	372.0	170.0	3.8	171.0	698
362	P22	A	254.7	1821.9	89/11/14		181.00		7.3		1400	7.6	1400	108.0	24.0	139.0	1.4	0.11	429.0	161.0	5.1	77.0	727
363	P22	A	254.7	1821.9	89/12/00		181.00																
364	P22	A	254.7	1821.9	90/01/16		181.00		6.6		1200	7.6	1370	107.0	26.0	138.0	1.2	0.00	418.0	171.0	4.3	65.0	719
365	P22	A	254.7	1821.9	90/02/06		181.00		6.6		1100	7.5	1340	115.0	22.0	128.0	1.4	0.00	416.0	163.0	5.4	77.0	716
366	P22	A	254.7	1821.9	90/03/07		181.00		6.6		1200	7.4	1410	114.0	21.0	135.0	1.1	0.00	413.0	165.0	4.8	75.0	720
367	P23	A	247.2	1829.1	89/03/00		201.00												52.0				
368	P23	A	247.2	1829.1	89/04/02	5.52	201.00	195.48											21.0				
369	P23	A	247.2	1829.1	89/05/02	5.70	201.00	195.30	6.9		700	7.1	660	46.0	6.6	98.0	12.0	1.80	0.2	21.0	37.0	0.0	408
370	P23	A	247.2	1829.1	89/06/01	7.00	201.00	194.00	7.2		600	7.0	692	47.0	6.0	98.0	7.6	3.60	412.0	19.0	46.0	0.0	426
371	P23	A	247.2	1829.1	89/07/05	6.29	201.00	194.71	7.5	22.6	700	7.2	711	50.0	7.0	94.0	13.0	53.00	411.0	19.0	47.0	0.0	433
372	P23	A	247.2	1829.1	89/08/02	8.57	201.00	192.43	7.7	30.6	700	7.3	746	60.0	2.7	86.0	13.0	0.48	386.0	29.0	48.0	0.0	428
373	P23	A	247.2	1829.1	89/09/10		201.00																
374	P23	A	247.2	1829.1	89/10/09		201.00																
375	P23	A	247.2	1829.1	89/11/14		201.00																
376	P23	A	247.2	1829.1	89/12/00		201.00																
377	P23	A	247.2	1829.1	90/01/00		201.00																
378	P23	A	247.2	1829.1	90/02/00		201.00																
379	P23	A	247.2	1829.1	90/03/00		201.00																
380	P31	A	256.7	1805.4	89/03/00		175.00																
381	P31	A	256.7	1805.4	89/04/00		175.00																
382	P31	A	256.7	1805.4	89/05/00		175.00																
383	P31	A	256.7	1805.4	89/06/08	6.90	175.00	168.10	7.5		800	7.4	842	20.0	3.3	182.0	3.7	0.41	521.0	25.0	0.0	0.5	491
384	P31	A	256.7	1805.4	89/07/10	6.31	175.00	168.69	6.6	30.6	1000	7.0	859	25.0	1.2	178.0	3.8	0.58	529.0	28.0	0.0	0.0	496
385	P31	A	256.7	1805.4	89/08/11	6.61	175.00	168.39	8.2	30.0	900	7.3	867	20.0	4.5	185.0	3.5	0.83	533.0	27.0	0.0	1.0	504
386	P31	A	256.7	1805.4	89/09/12	6.40	175.00	168.60	8.1		1000	7.2	902	23.0	13.0	180.0	3.5	1.30	494.0	39.0	0.0	1.3	502
387	P31	A	256.7	1805.4	89/10/12	6.12	175.00	168.88	7.4		900	7.9	873	18.0	7.4	186.0	4.1	0.94	523.0	33.0	0.0	0.0	550
388	P31	A	256.7	1805.4	89/11/15	6.27	175.00	168.73	7.6		1000	7.4	985	19.0	8.2	198.0	3.4	1.20	534.0	48.0	0.0	0.2	539
389	P31	A	256.7	1805.4	89/12/00		175.00																
390	P31	A	256.7	1805.4	90/01/19	6.18	175.00	168.82	7.0		900	7.3	908	20.0	5.3	188.0	2.5	2.40	526.0	40.0	0.0	0.9	515
391	P31	A	256.7	1805.4	90/02/16	6.17	175.00	168.83	6.8		800	7.4	897	20.0	5.7	182.0	3.3	2.10	528.0	39.0	0.5	1.4	511
392	P31	A	256.7	1805.4	90/03/14	6.28	175.00		7.1		800	6.7	942	22.0	5.3	184.0	2.4	0.09	542.0	39.0	0.0	0.8	520

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL m	ELA m	HEAD m	FpH	FTEMP °C	FEc µS	LpH	LEc µS	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	TDS mg/l
393	P32	A	254.3	1806.1	89/03/00		181.00																
394	P32	A	254.3	1806.1	89/04/00		181.00																
395	P32	A	254.3	1806.1	89/05/00		181.00																
396	P32	A	254.3	1806.1	89/06/08	8.10	181.00	172.90	7.1		1000	7.1	1080	96.0	22.0	116.0	2.3	0.57	611.0	68.0	6.8	0.8	613
397	P32	A	254.3	1806.1	89/07/10	8.00	181.00	173.00	7.5	29.4	1200	6.9	1080	114.0	11.0	122.0	2.8	0.24	632.0	64.0	4.7	0.3	630
398	P32	A	254.3	1806.1	89/08/11	8.21	181.00	172.79	6.7	26.5	1200	7.0	1110	108.0	17.0	117.0	2.6	0.97	625.0	81.0	1.2	1.0	636
399	P32	A	254.3	1806.1	89/09/13	8.70	181.00	172.30	7.6		1300	6.9	1150	88.0	30.0	120.0	3.0	1.00	587.0	76.0	1.2	0.3	608
400	P32	A	254.3	1806.1	89/10/19	7.14	181.00	173.86	7.3		1100	7.1	1110	74.0	44.0	109.0	2.8	0.77	611.0	71.0	0.0	0.0	602
401	P32	A	254.3	1806.1	89/11/15	7.00	181.00	174.00	7.8		1100	7.4	1100	95.0	24.0	114.0	2.1	0.48	597.0	62.0	0.0	0.0	592
402	P32	A	254.3	1806.1	89/12/00		181.00																
403	P32	A	254.3	1806.1	90/01/19	7.67	181.00	173.33	7.1		1200	7.2	1200	100.0	20.0	138.0	2.1	2.10	581.0	123.0	3.7	1.0	674
404	P32	A	254.3	1806.1	90/02/16	7.92	181.00	167.08	7.3		900	7.6	803	33.0	21.0	116.0	2.5	1.60	386.0	70.0	0.6	0.6	434
405	P32	A	254.3	1806.1	90/03/14	8.05	181.00		7.0		1000	6.7	1160	102.0	18.0	115.0	2.3	0.00	585.0	87.0	0.3	1.5	614
406	P34	A	249.9	1806.7	89/03/00		170.00																
407	P34	A	249.9	1806.7	89/04/00	4.90	170.00	165.10															
408	P34	A	249.9	1806.7	89/05/10	4.95	170.00	165.05	6.6		11200	6.9	14100	560.0	165.0	2250.0	47.0	3.20	390.0	4780.0	41.0	0.0	8040
409	P34	A	249.9	1806.7	89/06/06	4.93	170.00	165.07	6.8		10500	6.8	14200	612.0	141.0	2250.0	54.0	1.40	388.0	4740.0	47.0	0.0	8050
410	P34	A	249.9	1806.7	89/07/11	4.81	170.00	165.19	6.5		14100	7.7	13900	640.0	92.0	2200.0	675.0	6.60	459.0	4650.0	36.0	0.0	8520
411	P34	A	249.9	1806.7	89/08/11	4.93	170.00	165.07	6.6		13200	7.0	13800	360.0	260.0	2060.0	74.0	2.20	535.0	4480.0	9.5	4.2	7510
412	P34	A	249.9	1806.7	89/09/13	4.54	170.00	165.46	7.6		13900	6.8	13900	648.0	93.0	2080.0	53.0	0.94	375.0	4740.0	21.0	2.8	7820
413	P34	A	249.9	1806.7	89/10/19	4.72	170.00	165.28	7.5		12700	7.0	13800	560.0	141.0	2210.0	57.0	0.77	409.0	4520.0	6.7	1.6	7700
414	P34	A	249.9	1806.7	89/11/15	4.61	170.00	165.39	7.4	1.0	13200	7.8	14800	592.0	214.0	2220.0	45.0	0.67	219.0	4810.0	21.0	11.0	8020
415	P34	A	249.9	1806.7	89/12/00		170.00																
416	P34	A	249.9	1806.7	90/01/18	4.27	170.00	165.73	6.9		10300	7.0	14000	528.0	165.0	2250.0	33.0	5.50	327.0	4920.0	25.0	1.6	8080
417	P34	A	249.9	1806.7	90/02/16	5.05	170.00	164.95	7.0		7800	6.8	13800	496.0	165.0	2300.0	43.0	1.80	260.0	4650.0	28.0	2.0	7810
418	P34	A	249.9	1806.7	90/03/14	4.87	170.00		7.1		8200	6.8	14300	600.0	1120.0	2320.0	33.0	0.00	290.0	4590.0	2.0	1.5	7750
419	P68	A	255.1	1827.2	89/03/00		173.00																
420	P68	A	255.1	1827.2	89/04/02	4.19	173.00	168.81															
421	P68	A	255.1	1827.2	89/05/02	3.98	173.00	169.02	6.8		19900	7.1	134000	1480.0	498.0	44800.0	220.0	8.20	82.0	64500.0	4200.0	0.0	116000
422	P68	A	255.1	1827.2	89/06/01	4.30	173.00	168.70	6.9		19900	7.1	110000	1160.0	389.0	32000.0	245.0	1.00	162.0	50300.0	2420.0	0.0	86600
423	P68	A	255.1	1827.2	89/07/05	3.85	173.00	169.15	6.9		19900	6.8	96100	1140.0	365.0	25800.0	205.0	1.10	203.0	45200.0	1930.0	345.0	75100
424	P68	A	255.1	1827.2	89/08/02	3.92	173.00	169.08	7.2		19900	7.0	102000	1100.0	326.0	26000.0	210.0	1.50	203.0	42000.0	1790.0	49.0	71600
425	P68	A	255.1	1827.2	89/09/10	3.35	173.00	169.65	7.6		19900	7.1	92400	1140.0	292.0	25200.0	210.0	1.30	208.0	39900.0	1780.0	44.0	68700
426	P68	A	255.1	1827.2	89/10/09	3.42	173.00	169.58	6.9		19900	7.0	94300	896.0	384.0	25000.0	302.0	1.50	208.0	39300.0	1840.0	1.1	67800
427	P68	A	255.1	1827.2	89/11/14	3.27	173.00	169.73	6.7		19900	7.1	102000	1060.0	292.0	25700.0	228.0	1.50	213.0	40000.0	1930.0	0.0	69300
428	P68	A	255.1	1827.2	89/12/00		173.00																
429	P68	A	255.1	1827.2	90/01/16	3.80	173.00	169.20	6.5		19900	7.0	91500	888.0	141.0	25200.0	169.0	4.50	215.0	38800.0	2000.0	0.2	67500
430	P68	A	255.1	1827.2	90/02/06	3.82	173.00	169.18	6.5		19900	6.9	92400	880.0	341.0	2750.0	198.0	6.00	210.0	40000.0	1890.0	0.7	70900
431	P68	A	255.1	1827.2	90/03/07	4.00	168.70		6.8		19900	6.9	91200	939.0	316.0	2660.0	191.0	3.90	217.0	39700.0	1830.0	1.3	69700
432	P70	A	256.8	1824.8	89/03/00		182.00																
433	P70	A	256.8	1824.8	89/04/09	5.34	182.00	176.66															
434	P70	A	256.8	1824.8	89/05/02	5.38	182.00	176.62	6.6		19900	7.0	79300	1060.0	207.0	10000.0	408.0	3.10	103.0	18100.0	546.0	42.0	30400
435	P70	A	256.8	1824.8	89/06/02	5.36	182.00	176.64	6.8		19900	6.8	59900	1240.0	656.0	14400.0	260.0	3.10	199.0	24200.0	356.0	0.0	41200
436	P70	A	256.8	1824.8	89/07/11	5.01	182.00	176.99	7.3		19900	6.8	44300	1460.0	243.0	9300.0	189.0	0.75	250.0	17000.0	176.0	0.0	28400
437	P70	A	256.8	1824.8	89/08/02	5.26	182.00	176.74	6.6		19900	6.7	45200	1180.0	408.0	8650.0	216.0	0.84	249.0	16600.0	178.0	0.0	27400
438	P70	A	256.8	1824.8	89/09/12	4.87	182.00	177.13	7.5		19900	6.8	44100	1100.0	428.0	9160.0	186.0	1.20	239.0	16400.0	170.0	0.0	27600
439	P70	A	256.8	1824.8	89/10/09	5.00	182.00	177.00	7.5		19900	7.1	43200	1140.0	516.0	8670.0	258.0	1.50	246.0	15900.0	142.0	0.0	26700
440	P70	A	256.8	1824.8	89/11/14	5.00	182.00	177.00	7.3		19900	6.7	62500	1320.0	540.0	12400.0	255.0	1.10	211.0	22700.0	317.0	0.2	37600
441	P70	A	256.8	1824.8	89/12/09	5.00	182.00	177.00	7.7		19900	6.8	48700	1010.0	798.0	10300.0	237.0	0.90	250.0	18300.0	193.0	0.4	31000
442	P70	A	256.8	1824.8	90/01/16	5.20	182.00	176.80	6.7		19900	7.0	47500	1100.0	453.0	9670.0	163.0	3.50	281.0	17600.0	292.0	0.2	29400
443	P70	A	256.8	1824.8	90/02/06	5.32	182.00	176.68	6.8		19900	7.0	46300	1180.0	506.0	9320.0	211.0	5.70	263.0	17900.0	202.0	0.0	29500
444	P70	A	256.8	1824.8	90/03/07	5.35	182.00		7.2		19900	6.9	46200	1150.0	491.0	9600.0	178.0	0.66	282.0	17700.0	178.0	1.7	29400
445	P73	A	256.8	1812.4	89/03/00		155.00																
446	P73	A	256.8	1812.4	89/04/31	1.43	155.00	153.57															
447	P73	A	256.8	1812.4	89/05/10	1.50	155.00	153.50	7.5		7900	7.4	8470	14.0	44.0	1750.0	12.0	2.40	438.0	2510.0	140.0	5.6	4690
448	P73	A	256.8	1812.4	89/06/06	1.42	155.00	153.58	7.4		6800	7.3	8110	50.0	2.5	1680.0	15.0	1.90	437.0	2400.0	11.0	3.7	4380

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL m	ELA m	HEAD m	FpH	FTEMP °C	FEc µS	LpH	LEc µS	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	TDS mg/l
449	P73	A	256.8	1812.4	89/07/11	1.07	155.00	153.93	8.0	30.9	8500	7.3	8010	80.0	7.7	1600.0	15.0		470.0	2310.0	145.0	0.0	4390
450	P73	A	256.8	1812.4	89/08/09	1.04	155.00	153.96	6.9	25.6	8400	7.4	8000	28.0	54.0	1510.0	15.0	2.00	476.0	2280.0	114.0	6.2	4240
451	P73	A	256.8	1812.4	89/09/12	0.50	155.00	154.50	7.9		8300	7.4	7990	40.0	12.0	1650.0	14.0	1.70	441.0	2290.0	135.0	5.3	4360
452	P73	A	256.8	1812.4	89/10/18	0.27	155.00	154.73	7.4		8000	7.3	7970	37.0	82.0	1650.0	15.0	1.20	456.0	2290.0	126.0	0.5	4430
453	P73	A	256.8	1812.4	89/11/14	0.31	155.00	154.69	7.4		7800	7.4	8730	37.0	65.0	1760.0	12.0	1.40	510.0	2680.0	104.0	0.7	4910
454	P73	A	256.8	1812.4	89/12/00		155.00																
455	P73	A	256.8	1812.4	90/01/18	1.00	155.00	154.00	6.2		6800	7.2	8520	49.0	20.0	1800.0	9.3	2.80	476.0	2720.0	186.0	1.1	5020
456	P73	A	256.8	1812.4	90/03/14	1.31	155.00		7.1		6000	7.2	8370	36.0	14.0	1660.0	8.4	0.00	473.0	2280.0	98.0	0.8	4330
457	P73A	A	256.8	1812.4	89/11/14	1.37	157.31	155.94	7.4		6300	7.4	6860	82.0	42.0	1340.0	21.0	1.30	702.0	1510.0	489.0	204.0	4040
458	P73A	A	256.8	1812.4	89/12/00		157.31																
459	P73A	A	256.8	1812.4	90/01/18	2.18	157.31	155.13	6.5		1900	7.1	2170	45.0	17.0	336.0	17.0	0.66	313.0	466.0	90.0	25.0	1150
460	P73A	A	256.8	1812.4	90/02/16	2.50	157.31	154.81	7.5		2600	8.1	3170	52.0	27.0	546.0	19.0	2.30	369.0	660.0	195.0	46.0	1730
461	P73A	A	256.8	1812.4	90/03/14	2.38	157.31		7.1		4300	7.5	5960	81.0	34.0	1090.0	14.0	0.05	565.0	1220.0	437.0	111.0	3270
462	P76	A	268.9	1808.3	89/03/00		145.6																
463	P76	A	268.9	1808.3	89/04/00		145.6																
464	P76	A	268.9	1808.3	89/05/00		145.6																
465	P76	A	268.9	1808.3	89/06/08	8.49	145.6	137.11	6.7		19900	6.7	67400	1020.0	253.0	16300.0	278.0	3.50	168.0	24500.0	4570.0	16.0	47000
466	P76	A	268.9	1808.3	89/07/12	6.61	145.6	138.99	6.5		19900	6.5	65800	1000.0	304.0	17100.0	225.0	0.73	154.0	25900.0	4130.0	39.0	48700
467	P76	A	268.9	1808.3	89/08/10	8.38	145.6	137.22	7.5		19900	6.8	67800	960.0	353.0	16600.0	268.0	1.30	170.0	25700.0	4690.0	39.0	48700
468	P76	A	268.9	1808.3	89/09/16	8.01	145.6	137.59	7.5		19900	6.7	70000	1240.0	204.0	17100.0	287.0	0.94	164.0	25500.0	4570.0	7.5	49000
469	P76	A	268.9	1808.3	89/10/20	8.10	145.6	137.50	7.4		19900	6.8	67800	960.0	353.0	1660.0	268.0	1.30	170.0	25700.0	4690.0	39.0	48700
470	P76	A	268.9	1808.3	89/11/18	8.00	145.6	137.60	7.7		19900	7.6	68300	928.0	467.0	17100.0	212.0	0.55	217.0	25000.0	4840.0	0.0	48700
471	P76	A	268.9	1808.3	89/12/00		145.6																
472	P76	A	268.9	1808.3	90/01/18	7.14	145.6	138.46	6.2		19900	7.1	66800	888.0	331.0	16500.0	256.0	2.10	226.0	25500.0	4590.0	0.3	48200
473	P76	A	268.9	1808.3	90/02/17	8.55	145.6	137.05	7.1		19900	6.7	67900	976.0	321.0	1700.0	178.0	0.00	216.0	25500.0	4950.0	0.1	48000
474	P76	A	268.9	1808.3	90/03/15	8.50	145.6	137.10	6.8		19900	6.9	64000	944.0	720.0	1710.0	184.0	0.23	222.0	24300.0	5390.0	0.0	48700
475	P81	A	270.5	1811.4	89/03/00		145.46																
476	P81	A	270.5	1811.4	89/04/08	35.20	145.46	110.26															
477	P81	A	270.5	1811.4	89/05/11	17.00	145.46	128.46	7.0		1990	7.1	58800	120.0	365.0	15800.0	162.0	0.00	179.0	23700.0	990.0	6.2	41300
478	P81	A	270.5	1811.4	89/06/08	13.76	145.46	131.70	6.7		19900	6.7	62300	640.0	97.0	16000.0	184.0	18.00	188.0	23600.0	1280.0	17.0	41900
479	P81	A	270.5	1811.4	89/07/12	11.62	145.46	133.84	6.5	29.2	19900	6.7	51000	432.0	131.0	12600.0	124.0	0.46	179.0	19200.0	1150.0	27.0	33700
480	P81	A	270.5	1811.4	89/08/10	11.31	145.46	134.15	7.0		19900	7.2	53800	306.0	149.0	12500.0	117.0	0.91	188.0	20800.0	1090.0	37.0	35100
481	P81	A	270.5	1811.4	89/09/16	10.65	145.46	134.81	7.2		19900	6.8	55400	460.0	24.0	13200.0	128.0	0.68	174.0	20000.0	1070.0	0.5	35000
482	P81	A	270.5	1811.4	89/10/20	10.16	145.46	135.30	7.0		19900	6.9	53700	302.0	357.0	1340.0	1.3	0.64	190.0	20600.0	1110.0	0.3	35900
483	P81	A	270.5	1811.4	89/11/18	9.98	145.46	135.48	7.6		1900	6.9	54400	440.0	185.0	12900.0	104.0	0.62	190.0	20300.0	1220.0	0.0	35200
484	P81	A	270.5	1811.4	89/12/00		145.46																
485	P81	A	270.5	1811.4	90/01/18	9.81	145.46	135.65	6.3		19900	7.1	50900	544.0	49.0	13600.0	185.0	2.30	202.0	19900.0	1040.0	0.2	35500
486	P81	A	270.5	1811.4	90/02/17	10.04	145.46	135.42	7.2		19900	7.2	50100	416.0	180.0	1220.0	84.0	14.00	289.0	19300.0	1280.0	0.2	33600
487	P81	A	270.5	1811.4	90/03/15	10.54	145.46	134.92	6.6		19900	7.0	52700	296.0	389.0	1270.0	92.0	0.00	261.0	19700.0	1060.0	1.0	34400
488	P82	A	270.5	1811.4	89/03/00		145.5																
489	P82	A	270.5	1811.4	89/04/08	26.41	145.5	119.09															
490	P82	A	270.5	1811.4	89/05/11	13.98	145.5	131.52	6.7		19900	6.4	67300	1040.0	316.0	17700.0	131.0	0.94	90.0	27000.0	302.0	9.9	46500
491	P82	A	270.5	1811.4	89/06/08	11.12	145.5	134.38	6.7		19900	6.5	69900	1280.0	340.0	19300.0	224.0	3.00	97.0	27400.0	308.0	40.0	51700
492	P82	A	270.5	1811.4	89/07/12	9.30	145.5	136.20	7.3		19900	6.7	52300	1080.0	136.0	12500.0	132.0	0.81	101.0	19500.0	2360.0	24.0	35800
493	P82	A	270.5	1811.4	89/08/10	9.25	145.5	136.25	7.4		19900	6.8	36400	720.0	122.0	7780.0	87.0	8.00	134.0	12600.0	1850.0	6.2	23200
494	P82	A	270.5	1811.4	89/09/16	8.84	145.5	136.66	7.4		19900	6.7	54400	1040.0	170.0	13200.0	136.0	0.88	99.0	19400.0	1110.0	15.0	35100
495	P82	A	270.5	1811.4	89/10/20	8.16	145.5	137.34	6.7		19900	7.3	39800	672.0	175.0	9240.0	73.0	0.91	125.0	13900.0	1870.0	1.9	26000
496	P82	A	270.5	1811.4	89/11/18	8.91	145.5	136.59	7.4		19900	7.3	41900	728.0	200.0	9610.0	82.0	0.94	121.0	14800.0	2050.0	0.8	27500
497	P82	A	270.5	1811.4	89/12/00		145.5																
498	P82	A	270.5	1811.4	90/01/18	8.70	145.5	136.80	6.3		19900	7.3	34300	544.0	165.0	7190.0	52.0	1.90	146.0	11600.0	1690.0	0.9	21300
499	P82	A	270.5	1811.4	90/02/17	8.97	145.5	136.53	7.1		19900	6.9	42300	816.0	136.0	9910.0	62.0	2.70	136.0	14700.0	2250.0	0.8	27900
500	P82	A	270.5	1811.4	90/03/15	9.16	145.5	136.34	6.7		19900	7.0	42000	728.0	190.0	1090.0	70.0	1.60	142.0	15400.0	2450.0	1.0	29800
501	PWKS	A	267.6	1823.2	89/10/10	17.51	199.28	181.77	6.9		500	7.0	590	41.0	38.0	24.0	1.4	0.00	201.0	29.0	70.0	30.0	331
502	PWKS	A	267.6	1823.2	89/11/17	17.23	199.28	182.05	7.4		700	8.0	550	42.0	32.0	25.0	1.5	0.00	192.0	35.0	72.0	46.0	348
503	PWKS	A	267.6	1823.2	89/12/11	17.14	199.28	182.14	8.0		500	7.1	609	40.0	32.0	25.0	1.8	0.00	186.0	32.0	71.0	33.0	327
504	PWKS	A	267.6	1823.2	90/01/15	17.14	199.28	182.14	6.9		600	8.1	686	61.0	32.0	25.0	1.1	0.03	252.0	33.0	63.0	34.0	374

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
505	PWKS	A	267.6	1823.2	90/02/17	17.24	199.28	182.04	7.2		600	7.0	596	41.0	32.0	23.0	13.0	0.00	198.0	31.0	64.0	33.0	323
506	PWKS	A	267.6	1823.2	90/03/08	17.13	199.28		6.8		600	7.6	586	15.0	49.0	24.0	1.4	0.29	198.0	32.0	68.0	36.0	322
507	PWTW	A	267.8	1823.1	89/10/24		190.00		6.9		5800	7.3	1280	180.0	71.0	15.0	4.2	0.09	430.0	30.0	318.0	5.4	835
508	PWTW	A	267.8	1823.1	89/11/17		190.00		7.9		1300	7.5	1310	194.0	81.0	15.0	4.8	5.50	441.0	41.0	390.0	6.8	949
509	PWTW	A	267.8	1823.1	89/12/11		190.00		8.0		1400	7.4	1440	185.0	96.0	14.0	5.7	0.40	413.0	30.0	543.0	5.6	1080
510	PWTW	A	267.8	1823.1	90/01/15		190.00		6.9		1400	7.6	1540	168.0	110.0	17.0	4.1	0.29	419.0	2.9	563.0	3.7	1070
511	PWTW	A	267.8	1823.1	90/02/17		190.00		7.2		1300	7.6	1470	162.0	118.0	16.0	5.1	0.59	417.0	17.0	599.0	3.2	1120
512	PWTW	A	267.8	1823.1	90/03/08		190.00		6.7		1200	7.9	1100	77.0	101.0	19.0	4.8	0.23	126.0	25.0	449.0	3.5	740
513	SW20	A	251.6	1806.6	89/03/00																		
514	SW20	A	251.6	1806.6	89/04/12		0.00		7.2		500	6.5	570	14.0	3.8	71.0	14.0	3.40	86.0	116.0	24.0	2.6	288
515	SW20	A	251.6	1806.6	89/05/10		0.00		5.3		800	6.6	690	20.0	5.3	82.0	21.0	1.70	126.0	129.0	9.2	2.3	331
516	SW20	A	251.6	1806.6	89/06/06		0.00		7.5		700	6.5	581	23.0	4.8	62.0	26.0	2.20	69.0	119.0	4.1	22.0	295
517	SW20	A	251.6	1806.6	89/07/10		0.00		8.5	31.6	700	6.6	593	19.0	3.6	60.0	27.0	1.80	101.0	114.0	15.0	1.1	290
518	SW20	A	251.6	1806.6	89/08/11		0.00		7.0	33.2	700	6.5	531	21.0	2.6	54.0	20.0	1.70	67.0	108.0	12.0	16.0	267
519	SW20	A	251.6	1806.6	89/09/13		0.00		8.4		500	6.7	391	14.0	2.7	44.0	12.0	5.30	59.0	73.0	0.0	7.2	181
520	SW20	A	251.6	1806.6	89/10/19		0.00		8.2		100	6.5	155	7.7	2.6	18.0	2.3	1.90	57.0	20.0	0.3	1.9	81
521	SW20	A	251.6	1806.6	89/11/15		0.00		7.9		200	7.2	252	12.0	5.2	28.0	2.1	1.40	99.0	25.0	5.3	0.6	128
522	SW20	A	251.6	1806.6	89/12/00		0.00																
523	SW20	A	251.6	1806.6	90/01/19		0.00		6.6		200	7.1	351	15.0	4.3	48.0	3.1	5.50	140.0	42.0	0.0	2.0	184
524	SW20	A	251.6	1806.6	90/02/16		0.00		7.0		300	7.1	365	15.0	4.2	46.0	4.2	6.60	121.0	52.0	0.0	2.6	184
525	SW20	A	251.6	1806.6	90/03/14				7.2		400	7.1	387	17.0	6.4	46.0	3.3	0.38	141.0	47.0	5.2	3.0	198
526	SW21	A	263.6	1805.7	89/03/15		0.00		8.1		1800	7.9	1660	59.0	15.0	247.0	6.4	0.24	140.0	448.0	30.0	0.8	875
527	SW21	A	263.6	1805.7	89/04/08		0.00		7.4		1600	7.0	1900	62.0	18.0	285.0	7.0	0.25	136.0	502.0	26.0	0.3	968
528	SW21	A	263.6	1805.7	89/05/08		0.00		8.2		2200	7.1	2130	69.0	17.0	342.0	7.1	0.34	123.0	588.0	23.0	0.0	1110
529	SW21	A	263.6	1805.7	89/06/05		0.00		7.6		400	6.4	450	33.0	5.2	42.0	5.5	5.50	100.0	67.0	32.0	3.3	237
530	SW21	A	263.6	1805.7	89/07/04		0.00		28.3		8	7.1	432	35.0	6.4	39.0	3.4	0.75	113.0	64.0	19.0	1.0	224
531	SW21	A	263.6	1805.7	89/08/07		0.00		30.9		7	6.8	525	27.0	4.2	64.0	3.7	2.90	73.0	117.0	9.7	0.8	263
532	SW21	A	263.6	1805.7	89/09/08		0.00		7.8	27.5	900	7.3	976	41.0	9.8	116.0	2.1	0.58	121.0	206.0	19.0	0.7	455
533	SW21	A	263.6	1805.7	89/10/16		0.00		7.9		200	6.6	205	13.0	5.1	16.0	1.6	3.50	58.0	24.0	4.0	0.2	93
534	SW21	A	263.6	1805.7	89/11/16		0.00		8.0		300	7.7	270	22.0	7.0	23.0	1.3	1.40	85.0	47.0	0.0	0.3	143
535	SW21	A	263.6	1805.7	89/12/18		0.00		7.9		600	7.4	636	32.0	8.1	75.0	2.5	0.50	100.0	136.0	13.0	0.0	316
536	SW21	A	263.6	1805.7	90/01/14		0.00		7.0		900	7.3	976	41.0	9.8	116.0	2.1	0.58	121.0	206.0	19.0	0.7	455
537	SW21	A	263.6	1805.7	90/02/14		0.00		6.6		1200	7.4	1410	52.0	14.0	192.0	3.0	0.44	126.0	336.0	28.0	1.1	687
538	SW21	A	263.6	1805.7	90/03/12				7.1		1700	7.3	1990	26.0	47.0	294.0	4.1	0.26	130.0	533.0	32.0	0.5	1000
539	SW22	A	265.2	1809.6	89/03/15		0.00		8.1		1800	8.0	1650	60.0	13.0	247.0	6.3	0.41	135.0	438.0	30.0	0.0	861
540	SW22	A	265.2	1809.6	89/04/08				7.6		1300	6.7	1930	63.0	18.0	290.0	7.1	0.05	134.0	511.0	28.0	0.2	983
541	SW22	A	265.2	1809.6	89/05/08		0.00		8.1		2100	7.2	2300	67.0	12.0	356.0	7.4	0.32	125.0	606.0	26.0	0.2	114
542	SW22	A	265.2	1809.6	89/06/09		0.00		7.2		200	6.8	252	18.0	5.1	16.0	3.8	2.30	65.0	21.0	22.0	0.0	118
543	SW22	A	265.2	1809.6	89/07/08		0.00		8.8	29.6	400	7.2	319	32.0	5.3	22.0	7.8	1.90	115.0	32.0	21.0	0.8	173
544	SW22	A	265.2	1809.6	89/08/07		0.00		6.8	28.7	900	7.3	848	31.0	4.5	113.0	5.3	3.70	78.0	209.0	13.0	0.8	416
545	SW22	A	265.2	1809.6	89/09/16		0.00		8.0		200	7.3	222	18.0	2.8	14.0	2.6	2.10	64.0	17.0	8.4	0.7	94
546	SW22	A	265.2	1809.6	89/10/20		0.00		7.2		300	7.3	173	16.0	4.7	13.0	1.9	1.40	73.0	17.0	3.7	0.3	93
547	SW22	A	265.2	1809.6	89/11/16		0.00		8.0		300	7.8	272	22.0	6.9	23.0	1.6	1.30	79.0	51.0	5.2	0.7	149
548	SW22	A	265.2	1809.6	89/12/17		0.00		7.8		500	7.5	620	28.0	13.0	71.0	2.4	0.10	102.0	132.0	13.0	0.0	309
549	SW22	A	285.2	1809.6	90/01/18				6.6		800	7.4	990	45.0	10.0	122.0	1.9	0.38	118.0	224.0	18.0	0.0	480
550	SW22	A	265.2	1809.6	90/02/13		0.00		6.9		1100	7.2	1330	54.0	11.0	182.0	3.7	0.39	136.0	326.0	24.0	0.4	667
551	SW22	A	265.2	1809.6	90/03/15				7.0		1500	7.2	1740	50.0	26.0	244.0	4.0	0.26	104.0	457.0	28.0	0.2	861
552	SW23	A	262.9	1813.7	89/03/17		0.00		8.8		1500	6.7	1330	36.0	8.3	205.0	4.1	0.66	45.0	390.0	0.0	0.5	652
553	SW23	A	262.9	1813.7	89/04/08		0.00		7.3		1300	6.2	1560	41.0	10.0	250.0	4.1	1.20	40.0	449.0	5.3	0.3	779
554	SW23	A	262.9	1813.7	89/05/11		0.00		8.5		19 0	6.3	2100	68.0	9.2	343.0	6.6	0.30	31.0	638.0	0.8	0.2	1080
555	SW2	A	262.9	1813.7	89/06/09		0.00		8.5		1000	6.9	982	40.0	5.5	134.0	4.7	1.10	50.0	258.0	1.4	0.7	470
556	SW23	A	62.9	1813.7	89/07/09		0.00		10.3	32.9	2100	6.7	1390	49.0	9.2	185.0	5.3	1.30	48.0	386.0	4.2	1.0	663
557	SW23	A	262.9	1813.7	89/08/07		0.00		8.3	32.8	1500	7.1	1370	85.0	11.0	135.0	15.0	0.68	47.0	389.0	12.0	0.5	669
558	SW23	A	262.9	1813.7	89/09/17		0.00		7.6		1800	6.6	1510	90.0	7.8	166.0	13.0	1.30	61.0	413.0	1.4	0.5	723
559	SW23	A	262.9	1813.7	89/10/19		0.00		7.9		600	7.5	742	25.0	6.5	65.0	4.0	2.60	49.0	134.0	0.0	2.7	261
560	SW23	A	262.9	1813.7	89/11/18		0.00		8.1		500	7.4	547	23.0	7.2	74.0	3.2	1.30	79.0	129.0	0.9	0.5	277

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL	SUB-	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS
	NO.	BASIN				m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/i	mg/l	mg/l	mg/l	mg/l	mg/l
561	SW23	A	262.9	1813.7	89/12/00		0.00																
562	SW23	A	262.9	1813.7	90/01/15		0.00		7.1		900	7.3	947	34.0	5.5	124.0	4.1	1.30	97.0	218.0	3.4	2.2	439
563	SW23	A	262.9	1813.7	90/02/16		0.00		6.1		1000	6.9	759	54.0	9.4	132.0	11.0	1.10	68.0	280.0	25.0	14.0	559
564	SW23	A	262.9	1813.7	90/03/08				7.0		1100	7.3	1150	44.0	9.7	157.0	2.6	0.75	74.0	297.0	0.0	0.0	546
565	SW24	A	266.1	1817.5	89/03/15		0.00		8.3		500	7.3	501	18.0	3.4	69.0	7.0	0.43	56.0	119.0	5.0	0.0	249
566	SW24	A	266.1	1817.5	89/04/08		0.00		7.6		500	6.6	505	19.0	2.8	69.0	5.6	0.43	55.0	120.0	2.2	0.0	246
567	SW24	A	266.1	1817.5	89/05/11		0.00		7.0		550	6.6	505	18.0	4.2	74.0	7.2	0.44	55.0	127.0	0.9	0.0	258
568	SW24	A	266.1	1817.5	89/06/09		0.00		7.5		500	6.8	504	17.0	3.8	69.0	6.1	0.33	54.0	119.0	1.4	0.0	243
569	SW24	A	266.1	1817.5	89/07/09		0.00		6.7	29.7	700	6.9	494	18.0	3.9	64.0	6.9	0.76	59.0	118.0	3.5	1.2	244
570	SW24	A	266.1	1817.5	89/08/07		0.00		9.1	29.9	600	8.0	513	19.0	3.2	67.0	7.3	0.06	64.0	119.0	0.5	0.2	248
571	SW24	A	266.1	1817.5	89/09/16		0.00		8.0		500	7.3	508	21.0	1.3	67.0	6.8	0.31	54.0	114.0	0.0	0.1	236
572	SW24	A	266.1	1817.5	89/10/19				8.0		500	6.7	445	17.0	5.4	59.0	4.3	0.09	59.0	107.0	1.1	0.0	222
573	SW24	A	266.1	1817.5	89/11/18				7.6		600	7.7	479	20.0	2.5	66.0	4.6	0.09	62.0	114.0	0.6	0.0	239
574	SW24	A	266.1	1817.5	89/12/00																		
575	SW24	A	266.1	1817.5	90/01/15				6.9		600	8.0	596	8.8	6.9	5.1	1.4	4.00	66.0	7.8	4.7	0.0	66
576	SW24	A	266.1	1817.5	90/02/16				6.7		600	7.2	544	22.0	3.7	71.0	4.3	0.22	73.0	129.0	0.0	0.2	265
577	SW24	A	266.1	1817.5	90/03/08				6.9		500	7.4	557	20.0	5.5	80.0	4.5	0.40	71.0	129.0	4.0	0.0	279
578	U836	A	254.5	1826.2	89/03/09	7.19	180.00	172.81	7.1		2400	7.1	2500	289.0	7.2	126.0	1.1	0.00	377.0	400.0	88.0	504.0	1670
579	U836	A	254.5	1826.2	89/04/02	6.22	180.00	173.78	6.7		2400	7.0	2500	264.0	61.0	130.0	0.9	1.90	258.0	371.0	77.0	337.0	1370
580	U836	A	254.5	1826.2	89/05/02	6.30	180.00	173.70	6.7		2600	6.8	2490	304.0	58.0	134.0	0.8	1.80	379.0	377.0	77.0	578.0	1720
581	U836	A	254.5	1826.2	89/06/01	6.50	180.00	173.50	6.8		2300	6.8	2560	306.0	59.0	128.0	0.5	1.10	374.0	369.0	96.0	489.0	1630
582	U836	A	254.5	1826.2	89/07/05	4.22	180.00	175.78	7.0	23.9	2700	7.1	2620	325.0	46.0	128.0	0.8	3.30	383.0	353.0	85.0	468.0	1590
583	U836	A	254.5	1826.2	89/08/02	3.68	180.00	176.32															
584	U836	A	254.5	1826.2	89/09/10	3.40	180.00	176.60	7.5	29.5	2900	7.0	2600	310.0	62.0	125.0	1.0	3.20	374.0	365.0	82.0	454.0	1580
585	U836	A	254.5	1826.2	89/10/09	4.20	180.00	175.80	6.7		2800	6.9	2620	321.0	45.0	128.0	0.9	0.64	358.0	354.0	95.0	579.0	1700
586	U836	A	254.5	1826.2	89/11/07	4.59	180.00	175.41	7.5		2600	7.2	2970	322.0	52.0	200.0	1.8	0.45	380.0	353.0	98.0	509.0	1720
587	U836	A	254.5	1826.2	89/12/00		180.00																
588	U836	A	254.5	1826.2	90/01/16	5.47	180.00	174.53	6.6		2200	7.3	2550	324.0	29.0	114.0	0.6	0.39	369.0	368.0	98.0	308.0	1420
589	U836	A	254.5	1826.2	90/02/06	7.10	180.00	172.90	6.6		2200	7.3	2530	292.0	44.0	131.0	0.6	1.80	288.0	343.0	92.0	368.0	1410
590	U836	A	254.5	1826.2	90/03/07	7.15	180.00		7.0		2100	7.0	2650	298.0	53.0	133.0	0.5	0.33	382.0	347.0	87.0	309.0	1420
591	WW1	A	247.2	1829.1	89/03/00		203.89																
592	WW1	A	247.2	1829.1	89/04/02		203.89																
593	WW1	A	247.2	1829.1	89/05/02		203.89																
594	WW1	A	247.2	1829.1	89/06/01	9.82	203.89	194.07	6.7		400	6.5	322	42.0	6.9	12.0	1.9	26.00	171.0	12.0	8.0	0.3	168
595	WW1	A	247.2	1829.1	89/07/05	9.50	203.89	194.39	7.0	24.0	400	6.7	290	42.0	3.0	13.0	4.0	31.00	161.0	12.0	0.0	1.0	154
596	WW1	A	247.2	1829.1	89/08/02	9.91	203.89	193.98	7.4	30.4	300	6.8	284	32.0	2.3	18.0	5.2	23.00	172.0	13.0	0.0	0.7	159
597	WW1	A	247.2	1829.1	89/09/10	9.80	203.89	194.05	7.9	29.9	200	7.0	229	29.0	1.9	11.0	6.6	14.00	122.0	11.0	0.0	6.3	125
598	WW1	A	247.2	1829.1	89/10/09	9.32	203.89	194.57	7.8		300	7.0	264	30.0	4.0	13.0	6.1	14.00	121.0	14.0	0.0	7.6	134
599	WW1	A	247.2	1829.1	89/11/14	8.53	203.89	195.36	7.5		400	6.6	330	31.0	5.5	15.0	5.2	25.00	148.0	19.0	0.5	2.1	150
600	WW1	A	247.2	1829.1	89/12/09	8.57	203.89	195.32	7.4		300	6.6	317	32.0	4.9	15.0	6.4	22.00	153.0	18.0	0.5	4.1	157
601	WW1	A	247.2	1829.1	90/01/09	8.77	203.89	195.12	7.6		300	6.9	380	29.0	7.1	17.0	6.1	18.00	158.0	20.0	0.0	0.9	157
602	WW1	A	247.2	1829.1	90/02/06	9.02	203.89	194.87	7.0		400	6.6	417	26.0	6.6	47.0	6.6	33.00	189.0	31.0	0.0	2.2	212
603	WW1	A	247.2	1829.1	90/03/07	9.23	203.89		7.7		400	6.6	336	30.0	6.9	24.0	5.8	36.00	129.0	18.0	0.3	40.0	190
604	WW11	A	254.3	1806.1	89/08/11	8.68	176.61	167.93	6.7	31.9	1100	7.5	936	88.0	17.0	104.0	1.8	0.47	581.0	36.0	0.0	0.9	534
605	WW11	A	254.3	1806.1	89/09/13	8.67	176.61	167.94	7.5		1000	7.2	888	68.0	15.0	119.0	2.2	0.75	504.0	33.0	0.6	0.0	486
606	WW11	A	254.3	1806.1	89/10/19		176.61		7.5		1000	7.1	980	85.0	25.0	106.0	1.7	0.00	588.0	41.0	0.0	0.0	549
607	WW11	A	254.3	1806.1	89/11/15		176.61		7.6		1100	7.4	1020	90.0	24.0	103.0	1.5	0.17	601.0	44.0	0.0	0.0	558
608	WW11	A	254.3	1806.1	89/12/13	8.00	176.61	168.61															
609	WW11	A	254.3	1806.1	90/01/19	8.25	176.61	168.36	6.6		900	7.2	988	90.0	17.0	103.0	1.0	0.17	595.0	39.0	0.0	0.4	544
610	WW11	A	254.3	1806.1	90/03/14	8.65	176.61		6.9		900	7.2	1030	91.0	23.0	101.0	1.0	0.00	579.0	40.0	0.0	0.7	542
611	WW19	A	270.5	1811.4	89/08/10	8.28	145.35	137.07	7.1	27.5	2100	7.2	3880	6.0	68.0	736.0	2.8	0.08	328.0	1060.0	8.8	1.6	2020
612	WW19	A	270.5	1811.4	89/09/16	7.91	145.35	137.44	7.2		1100	9.1	1060	29.0	0.5	173.0	7.1	1.10	40.0	236.0	75.0	0.8	541
613	WW19	A	270.5	1811.4	89/10/20	7.00	145.35	138.35	8.4		1800	7.6	1250	29.0	3.6	210.0	7.2	1.30	55.0	307.0	78.0	2.5	663
614	WW19	A	270.5	1811.4	89/11/18	7.25	145.35	138.10	7.5		1600	7.6	1300	30.0	20.0	185.0	47.0	1.10	85.0	295.0	104.0	3.4	726
615	WW19	A	270.5	1811.4	89/12/00		145.35																
616	WW19	A	270.5	1811.4	90/01/18	8.20	145.35	137.15	6.1		1800	7.4	1520	19.0	9.5	232.0	4.1	0.15	95.0	355.0	100.0	2.8	806

Appendix 1.3.1 Montly monitoring water level and chemical compositions of groundwater and surface water in Huai Yai Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
617	WW19	A	270.5	1811.4	90/02/17	8.36	145.35	136.99	7.1		1100	7.4	1170	28.0	2.7	162.0	37.0	1.70	114.0	251.0	66.0	5.3	609
618	WW19	A	270.5	1811.4	90/03/15	8.33	145.35		6.7		1700	7.2	1360	22.0	4.9	214.0	39.0	1.10	104.0	311.0	31.0	3.1	676
619	WW2	A	254.7	1821.9	89/03/00		177.77																
620	WW2	A	254.7	1821.9	89/04/09		177.77																
621	WW2	A	254.7	1821.9	89/05/02		177.77																
622	WW2	A	254.7	1821.9	89/06/01	5.13	177.77	172.64	7.4		700	7.5	737	16.0	2.8	148.0	1.1	12.00	351.0	70.0	2.5	0.0	414
623	WW2	A	254.7	1821.9	89/07/11		177.77																
624	WW2	A	254.7	1821.9	89/08/02		177.77																
625	WW2	A	254.7	1821.9	89/09/10	3.40	177.77	174.37	8.3			6.3	73	8.0	0.8	3.2	2.6	8.30	33.0	3.4	1.9	1.1	37
626	WW2	A	254.7	1821.9	89/10/09	4.29	177.77	173.48	6.8		1200	6.8	495	49.0	8.3	47.0	1.3	1.20	255.0	32.0	0.0	0.0	263
627	WW2	A	254.7	1821.9	89/11/14	4.06	177.77	173.71	7.0		900	7.6	884	73.0	10.0	83.0	1.0	18.00	367.0	78.0	3.2	0.0	429
628	WW2	A	254.7	1821.9	89/12/00		177.77																
629	WW2	A	254.7	1821.9	90/01/00		177.77																
630	WW2	A	254.7	1821.9	90/02/00		177.77																
631	WW2	A	254.7	1821.9	90/03/07	4.56	177.77		6.7		500	7.1	465	37.0	4.1	48.0	1.6	4.20	217.0	34.0	0.2	2.3	234
632	WW7	A	263.2	1814.4	89/03/00		155.91																
633	WW7	A	263.2	1814.4	89/04/00		155.91		7.9		3800	7.6	3880	48.0	4.9	750.0	3.6	4.10	194.0	1120.0	3.4	1.5	2030
634	WW7	A	263.2	1814.4	89/05/24	2.89	155.91	153.02	8.0		3900	7.8	3960	56.0	0.0	760.0	3.6	3.50	196.0	1130.0	2.3	0.9	2050
635	WW7	A	263.2	1814.4	89/06/09	2.72	155.91	153.19	7.6		3000	8.0	3340	46.0	4.4	670.0	3.0	3.70	201.0	936.0	1.3	0.7	1760
636	WW7	A	263.2	1814.4	89/07/09	2.20	155.91	153.71	6.2	28.2	2500	7.7	2220	15.0	7.3	443.0	2.3	2.30	233.0	600.0	2.4	1.0	1190
637	WW7	A	263.2	1814.4	89/08/07	2.01	155.91	153.90	8.9	30.5	1500	8.4	1750	8.8	1.9	336.0	2.0	1.70	241.0	415.0	0.5	0.5	891
638	WW7	A	263.2	1814.4	89/09/16	1.30	155.91	154.61	8.0		1900	8.2	1830	11.0	4.3	393.0	2.0	1.10	235.0	433.0	3.3	0.3	962
639	WW7	A	263.2	1814.4	89/10/19	1.01	155.91	154.90	8.2		1800												
640	WW7	A	263.2	1814.4	89/11/18	1.08	155.91	154.83	8.1		2000	8.4	1810	12.0	2.9	368.0	1.4	1.20	219.0	470.0	0.0	0.8	971
641	WW7	A	263.2	1814.4	89/12/00		155.91																
642	WW7	A	263.2	1814.4	90/01/15		155.91		6.9		2200	8.0	2420	9.8	3.6	505.0	2.1	9.90	226.0	624.0	0.7	0.7	1260
643	WW7	A	263.2	1814.4	90/02/16	2.23	155.91	153.68	6.8		2800	7.8	3310	25.0	5.8	627.0	1.8	8.10	207.0	941.0	1.7	0.0	1700
644	WW7	A	263.2	1814.4	90/03/08	2.44	155.91		7.1		2700	7.8	3070	29.0	8.3	590.0	2.9	11.00	213.0	811.0	0.0	0.0	1550

Table1.3.2 Montly monitoring water levels and chemical compositions of groundwater and surface water in Chonnabot Hydrogeologic Province

No.	WELL	SUB-	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
	NO.	BASIN				m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	L791	B	249.8	1799.5	89/03/11	3.00	171.00	168.00	7.0		9500	7.1	8540	56.0	56.0	1730.0	190.0	1.30	688.0	2030.0	585.0	525.0	5520	
2	L791	B	249.8	1799.5	89/04/10	3.17	171.00	167.83	6.6		4400	7.1	8200	50.0	51.0	1530.0	143.0	1.20	720.0	1650.0	427.0	709.0	4920	
3	L791	B	249.8	1799.5	89/05/10	2.95	171.00	168.05	6.5		8000	7.1	8650	60.0	41.0	1800.0	149.0	6.60	730.0	1910.0	403.0	409.0	5130	
4	L791	B	249.8	1799.5	89/06/06	2.52	171.00	168.48	6.8		6700	7.0	7390	122.0	50.0	1250.0	273.0	1.40	686.0	1450.0	310.0	865.0	4650	
5	L791	B	249.8	1799.5	89/07/11	1.90	171.00	169.10	7.2	32.4	8200	6.9	7580	8.0	207.0	950.0	493.0	2.20	473.0	1490.0	398.0	849.0	4630	
6	L791	B	249.8	1799.5	89/08/08	1.86	171.00	169.14	8.2	29.2	8400	7.2	8430	304.0	101.0	805.0	648.0	0.28	408.0	1730.0	297.0	1040.0	5012	
7	L791	B	249.8	1799.5	89/09/13	1.48	171.00	169.52	7.4		8100	6.9	7720	232.0	95.0	850.0	630.0	0.40	405.0	1560.0	346.0	669.0	4580	
8	L791	B	249.8	1799.5	89/10/18	0.87	171.00	170.13	7.0		7700	7.3	7420	192.0	151.0	818.0	463.0	0.66	439.0	1510.0	342.0	853.0	5470	
9	L791	B	249.8	1799.5	89/11/15	1.70	171.00	169.30	7.6		6400	7.2	6590	148.0	84.0	810.0	382.0	0.65	466.0	1200.0	231.0	571.0	3660	
10	L791	B	249.8	1799.5	89/12/13	2.40	171.00	168.60	7.4		7100	8.2	7360	80.0	137.0	1060.0	356.0	0.30	449.0	1510.0	682.0	402.0	4450	
11	L791	B	249.8	1799.5	90/01/17	2.61	171.00	168.39	6.6		6700	8.6	8130	118.0	152.0	1260.0	193.0	1.40	339.0	1730.0	534.0	341.0	4540	
12	L791	B	249.8	1799.5	90/02/16	2.91	171.00	168.09	6.5		6800	7.4	8560	117.0	75.0	1500.0	192.0	1.70	595.0	2130.0	526.0	280.0	5110	
13	L791	B	249.8	1799.5	90/03/13	3.35	171.00	167.65	7.0		5400	7.3	8040	89.0	77.0	1490.0	138.0	0.10	622.0	1650.0	453.0	348.0	4550	
14	L791	B	249.8	1799.5	90/04/09	2.80	171.00	168.20	7.2		5000	7.5	7280	88.0	44.0	1400.0	144.0	0.11	658.0	1540.0	410.0	343.0	4300	
15	P45	B	242.3	1800.6	89/03/00		204.00																	
16	P45	B	242.3	1800.6	89/04/10	6.81	204.00	197.19																
17	P45	B	242.3	1800.6	89/05/09	6.83	204.00	197.17	7.4		800	7.1	890	79.0	7.1	123.0	2.1	2.60	296.0	21.0	194.0	0.0	572	
18	P45	B	242.3	1800.6	89/06/06	6.54	204.00	197.46	7.3		700	6.9	774	59.0	4.2	98.0	2.2	1.50	219.0	21.0	181.0	0.3	471	
19	P45	B	242.3	1800.6	89/07/11	5.89	204.00	198.11	6.5	30.1	900	7.2	764	58.0	3.0	106.0	2.4	5.60	207.0	16.0	153.0	0.0	441	
20	P45	B	242.3	1800.6	89/08/09	6.16	204.00	197.84	6.6	30.8	1000	7.3	788	56.0	7.1	102.0	2.4	4.60	213.0	23.0	185.0	0.9	481	
21	P45	B	242.3	1800.6	89/09/13	5.71	204.00	198.29	8.4		800	7.1	785	55.0	4.6	102.0	2.4	1.30	200.0	20.0	195.0	0.6	478	
22	P45	B	242.3	1800.6	89/10/19	5.03	204.00	198.97	7.8		900	7.0	765	54.0	5.7	101.0	2.4	0.42	219.0	21.0	176.0	0.2	536	
23	P45	B	242.3	1800.6	89/11/15	5.13	204.00	198.87	7.7		900	7.3	888	57.0	7.5	114.0	2.0	0.48	221.0	40.0	170.0	1.5	501	
24	P45	B	242.3	1800.6	89/12/00		204.00																	
25	P45	B	242.3	1800.6	90/01/16	5.79	204.00	198.21	6.5		1000	7.0	1060	60.0	21.0	145.0	3.5	3.90	273.0	95.0	155.0	0.4	614	
26	P45	B	242.3	1800.6	90/02/15	6.00	204.00	198.00	7.0		800	7.2	893	67.0	4.7	115.0	6.6	4.10	337.0	54.0	107.0	0.0	520	
27	P45	B	242.3	1800.6	90/03/14	6.14	204.00	197.86	6.7		700	7.2	854	66.0	5.9	108.0	4.3	0.00	411.0	33.0	68.0	0.3	488	
28	P45	B	242.3	1800.6	90/04/10	6.00	204.00	198.00	7.2		800	7.2	857	66.0	7.3	112.0	5.2	0.11	347.0	34.0	142.0	6.2	544	
29	P48	B	245.9	1786.4	89/03/00		170.00																	
30	P48	B	245.9	1786.4	89/04/10		170.00																	
31	P48	B	245.9	1786.4	89/05/10		170.00																	
32	P48	B	245.9	1786.4	89/06/06	11.31	170.00	158.69	7.2		5100	7.2	6470	520.0	367.0	680.0	9.3	6.30	280.0	719.0	3050.0	0.0	5480	
33	P48	B	245.9	1786.4	89/07/10	11.09	170.00	158.91	7.5	30.4	6800	7.0	6400	526.0	334.0	630.0	9.5	0.42	247.0	764.0	3180.0	0.2	5570	
34	P48	B	245.9	1786.4	89/08/08	11.63	170.00	158.37	6.8	29.1	6700	6.9	6480	508.0	320.0	686.0	9.6	0.00	238.0	798.0	2350.0	6.9	4800	
35	P48	B	245.9	1786.4	89/09/13	11.40	170.00	158.60	8.0		6800	7.0	6200	506.0	362.0	712.0	10.0	4.40	270.0	748.0	3180.0	7.0	5660	
36	P48	B	245.9	1786.4	89/10/18		170.00		7.0	11.8	6700	7.9	6390	480.0	375.0	735.0	10.0	2.70	177.0	793.0	2970.0	0.0	5950	
37	P48	B	245.9	1786.4	89/11/15	12.04	170.00	157.96	7.8		6800	7.8	7320	434.0	585.0	691.0	7.4	1.80	393.0	734.0	3280.0	0.5	5930	
38	P48	B	245.9	1786.4	89/12/00		170.00																	
39	P48	B	245.9	1786.4	90/01/17	12.15	170.00	157.85	6.3		5100	7.8	6570	528.0	437.0	675.0	6.9	1.90	355.0	744.0	3280.0	0.7	5880	
40	P48	B	245.9	1786.4	90/02/16	12.39	170.00	157.61	6.3		4100	7.1	6700	498.0	424.0	750.0	9.0	4.00	346.0	675.0	3410.0	0.9	5940	
41	P48	B	245.9	1786.4	90/03/13	12.53	170.00	157.47	7.0		4100	7.1	9190	534.0	480.0	716.0	7.0	0.00	419.0	687.0	3500.0	1.8	6130	
42	P48	B	245.9	1786.4	90/04/09	12.33	170.00	157.67	7.1		3700	7.3	6130	736.0	417.0	639.0	5.5	0.00	426.0	596.0	4120.0	1.4	6730	
43	P49	B	245.9	1786.4	89/03/00		170.00																	
44	P49	B	245.9	1786.4	89/04/10	8.56	170.00	161.44																
45	P49	B	245.9	1786.4	89/05/10	9.40	170.00	160.60	6.7		5800	7.1	6550	546.0	570.0	465.0	7.9	22.00	688.0	541.0	3550.0	0.3	6020	
46	P49	B	245.9	1786.4	89/06/06	7.65	170.00	162.35	7.0		4600	7.1	5610	508.0	453.0	430.0	5.6	0.50	682.0	714.0	2600.0	0.6	4750	
47	P49	B	245.9	1786.4	89/07/10	6.30	170.00	163.70	7.3	30.3	6000	7.1	5590	418.0	521.0	400.0	5.4	0.85	688.0	447.0	3050.0	0.2	5180	
48	P49	B	245.9	1786.4	89/08/08	4.93	170.00	165.07	7.7	30.0	5800	7.0	5620	384.0	472.0	396.0	4.4	0.86	680.0	516.0	2620.0	2.7	4730	
49	P49	B	245.9	1786.4	89/09/13	4.76	170.00	165.24	7.7		6000	7.0	5410	386.0	486.0	425.0	4.8	0.63	685.0	506.0	2810.0	1.5	4960	
50	P49	B	245.9	1786.4	89/10/18		170.00		7.0	27.1	4000	7.4	3860	212.0	301.0	315.0	2.7	0.72	563.0	369.0	1190.0	7.3	2670	
51	P49	B	245.9	1786.4	89/11/15	3.29	170.00	166.71	7.9		2700	7.3	2810	166.0	187.0	189.0	2.4	0.37	459.0	267.0	677.0	6.0	1720	
52	P49	B	245.9	1786.4	89/12/00		170.00																	
53	P49	B	245.9	1786.4	90/01/17	9.45	170.00	160.55	6.4		2400	8.1	2580	98.0	176.0	228.0	3.4	0.38	197.0	335.0	809.0	7.2	1750	
54	P49	B	245.9	1786.4	90/02/16		170.00																	
55	P49	B	245.9	1786.4	90/03/13		170.00																	
56	P49	B	245.9	1786.4	90/04/09		170.00																	

Table1.3.2 Montly monitoring water levels and chemical compositions of groundwater and surface water in Chonnabot Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	μS		μS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
57	P50	B	249.4	1789.5	89/03/00		160.00																	
58	P50	B	249.4	1789.5	89/04/10	1.69	160.00	158.31																
59	P50	B	249.4	1789.5	89/05/10	1.62	160.00	158.38																
60	P50	B	249.4	1789.5	89/06/06	0.65	160.00	159.35	7.0		3500	6.8	4010	217.0	42.0	510.0	31.0	0.82	494.0	841.0	113.0	212.0	2000	
61	P50	B	249.4	1789.5	89/07/10	1.00	160.00	159.00	6.5	32.7	4500	6.8	4020	214.0	49.0	600.0	30.0	0.71	480.0	853.0	231.0	173.0	2390	
62	P50	B	249.4	1789.5	89/08/08	1.05	160.00	158.95	8.4	30.5	4200	6.9	3820	200.0	40.0	500.0	29.0	0.86	487.0	790.0	185.0	171.0	2160	
63	P50	B	249.4	1789.5	89/09/13	0.97	160.00	159.03	7.3		4300	6.8	3800	208.0	55.0	533.0	43.0	3.50	611.0	820.0	171.0	47.0	2180	
64	P50	B	249.4	1789.5	89/10/17	0.49	160.00	159.51	7.0		4100	7.0	3860	214.0	42.0	544.0	34.0	0.36	573.0	808.0	155.0	256.0	2430	
65	P50	B	249.4	1789.5	89/11/15	0.92	160.00	159.08	7.9		4200	8.0	4200	210.0	70.0	572.0	30.0	0.45	518.0	829.0	167.0	196.0	2330	2480
66	P50	B	249.4	1789.5	89/12/00		160.00																	
67	P50	B	249.4	1789.5	90/01/17	1.46	160.00	158.54	6.7		3200	7.0	4160	172.0	80.0	620.0	25.0	2.50	659.0	859.0	216.0	87.0	2380	
68	P50	B	249.4	1789.5	90/02/16	1.53	160.00	158.47	7.0		3200	6.9	4230	213.0	39.0	585.0	25.0	3.70	483.0	827.0	213.0	222.0	2370	
69	P50	B	249.4	1789.5	90/03/13	1.64	160.00	158.36	7.1		2800	7.0	4000	215.0	61.0	558.0	31.0	0.29	792.0	822.0	181.0	0.0	2260	
70	P50	B	249.4	1789.5	90/04/09	1.09	160.00	158.91	7.3		1400	7.1	2100	93.0	25.0	276.0	11.0	0.00	468.0	388.0	32.0	2.0	1060	
71	SB32	B	250.6	1792.8	89/03/19	4.56	159.00	154.44	9.4		3000	7.3	2910	96.0	20.0	500.0	4.2	1.10	541.0	709.0	7.4	0.2	1603	
72	SB32	B	250.6	1792.8	89/04/10	4.94	159.00	154.06	6.8		2400	7.3	2910	86.0	21.0	510.0	4.5	0.25	529.0	681.0	6.6	0.7	1570	
73	SB32	B	250.6	1792.8	89/05/10	4.31	159.00	154.69	7.3		2300	7.5	2400	45.0	12.0	445.0	5.9	0.40	347.0	582.0	2.8	0.3	1260	
74	SB32	B	250.6	1792.8	89/06/06	6.97	159.00	152.03	7.0		2800	7.1	3160	130.0	22.0	520.0	3.8	0.03	610.0	729.0	9.0	0.4	1710	
75	SB32	B	250.6	1792.8	89/07/10	3.09	159.00	155.91	6.5	36.0	3700	7.1	3090	115.0	33.0	490.0	3.5	4.30	574.0	729.0	8.1	0.0	1660	
76	SB32	B	250.6	1792.8	89/08/08	3.36	159.00	155.64	8.4	29.7	3300	7.3	3100	99.0	26.0	482.0	3.8	0.33	557.0	735.0	6.9	0.8	1630	
77	SB32	B	250.6	1792.8	89/09/13	2.52	159.00	156.48	7.5		3500	7.1	2940	102.0	25.0	512.0	4.1	1.20	543.0	717.0	6.4	0.7	1640	
78	SB32	B	250.6	1792.8	89/10/18	2.50	159.00	156.50	7.0		3400	7.1	3170	118.0	27.0	502.0	4.0	0.17	588.0	738.0	6.4	0.0	1800	
79	SB32	B	250.6	1792.8	89/11/15	2.82	159.00	156.18	7.9		3200	7.2	3200	103.0	33.0	585.0	3.3	2.90	514.0	942.0	5.3	0.5	1950	
80	SB32	B	250.6	1792.8	89/12/13	3.36	159.00	155.64	7.6		2800	8.1	2700	70.0	22.0	500.0	5.1	0.10	433.0	655.0	84.0	0.0	1550	
81	SB32	B	250.6	1792.8	90/01/17	4.73	159.00	154.27	6.6		2000	8.5	2310	34.0	4.9	443.0	5.1	0.28	238.0	564.0	2.2	0.6	1190	
82	SB32	B	250.6	1792.8	90/02/16	4.73	159.00	154.27	6.7		2000	7.8	2420	35.0	12.0	424.0	3.9	0.11	334.0	571.0	2.8	0.5	1210	
83	SB32	B	250.6	1792.8	90/03/13	4.36	159.00	154.64	6.9		2200	7.1	2870	83.0	17.0	449.0	3.8	0.00	473.0	635.0	5.0	0.5	1430	
84	SB32	B	250.6	1792.8	90/04/09	1.98	159.00	157.02	7.3		2100	7.7	2860	93.0	19.0	488.0	2.5	0.00	502.0	660.0	5.7	0.0	1520	
85	SW15	B	249.9	1789.2	89/03/19				9.4		2200	7.0	1960	63.0	15.0	305.0	6.6	0.84	131.0	529.0	33.0	0.0	1020	
86	SW15	B	249.9	1789.2	89/04/10				7.2		1900	6.9	2240	70.0	17.0	350.0	8.2	0.55	132.0	606.0	30.0	0.7	1150	
87	SW15	B	249.9	1789.2	89/05/10				7.2		2600	7.1	2380	63.0	20.0	295.0	8.5	1.30	65.0	695.0	23.0	0.0	1200	
88	SW15	B	249.9	1789.2	89/06/06				7.7		200	6.6	159	18.0	1.7	9.0	3.9	3.10	66.0	9.1	22.0	2.9	99	
89	SW15	B	249.9	1789.2	89/07/10				6.5	33.6	400	6.6	257	22.0	3.6	23.0	2.4	4.20	82.0	35.0	0.7	0.6	127	
90	SW15	B	249.9	1789.2	89/08/08				8.9	30.8	600	6.8	471	29.0	5.7	48.0	3.0	1.80	91.0	93.0	15.0	1.0	239	
91	SW15	B	249.9	1789.2	89/09/13				8.0		200	6.8	167	17.0	2.9	13.0	2.1	1.70	64.0	19.0	10.0	0.7	96	
92	SW15	B	249.9	1789.2	89/10/18				7.6		200	6.8	163	14.0	4.2	11.0	2.1	1.30	68.0	16.0	0.6	0.7	64	
93	SW15	B	249.9	1789.2	89/11/15				8.0		300	7.0	279	20.0	8.3	24.0	1.8	1.50	87.0	43.0	3.2	0.0	143	
94	SW15	B	249.9	1789.2	89/12/00																			
95	SW15	B	249.9	1789.2	90/01/17				6.7		900	7.7	1060	45.0	11.0	157.0	2.7	0.44	125.0	255.0	19.0	0.0	551	
96	SW15	B	249.9	1789.2	90/02/16				6.9		1400	7.3	1580	61.0	18.0	242.0	4.3	0.79	129.0	390.0	27.0	1.1	806	
97	SW15	B	240.3	1781.2	90/03/13				7.1		1400	6.5	1630	64.0	15.0	231.0	6.2	0.57	153.0	401.0	37.0	0.3	830	
98	SW15	B	249.9	1789.2	90/04/09				7.2		1300	7.5	1420	53.0	16.0	214.0	3.5	0.34	144.0	337.0	32.0	0.7	725	
99	SW18	B	250.6	1793.2	89/03/19				9.9		2000	6.9	1820	58.0	19.0	271.0	6.9	1.10	143.0	487.0	33.0	0.3	946	
100	SW18	B	250.6	1793.2	89/04/10				7.2		1800	6.9	2100	56.0	20.0	320.0	7.9	0.20	129.0	553.0	29.0	0.5	1050	
101	SW18	B	250.6	1793.2	89/05/10				4.0		2400	6.9	2230	61.0	21.0	345.0	8.3	0.07	185.0	606.0	27.0	0.0	1160	
102	SW18	B	250.6	1793.2	89/06/06				7.7		100	7.0	156	19.0	0.6	10.0	3.9	2.40	59.0	7.5	26.0	3.1	99	
103	SW18	B	250.6	1793.2	89/07/10				6.4	33.2	400	6.6	271	26.0	3.5	22.0	2.5	6.40	92.0	33.0	14.0	1.3	147	
104	SW18	B	250.6	1793.2	89/08/08				9.0	29.4	500	6.7	478	29.0	5.6	49.0	2.9	1.60	85.0	96.0	14.0	0.7	238	
105	SW18	B	250.6	1793.2	89/09/13				8.1		200	7.1	188	20.0	1.9	14.0	2.5	2.20	71.0	20.0	7.9	2.4	104	
106	SW18	B	250.6	1793.2	89/10/18				7.5		200	7.5	187	17.0	3.0	14.0	2.3	1.80	60.0	21.0	4.3	1.7	93	
107	SW18	B	250.6	1793.2	89/11/15				7.6		300	6.9	300	21.0	8.1	25.0	1.7	1.50	81.0	44.0	0.0	1.4	141	
108	SW18	B	250.6	1793.2	89/12/13				7.6		600	7.5	582	30.0	8.2	68.0	2.0	0.40	96.0	122.0	12.0	0.0	290	
109	SW18	B	250.6	1793.2	90/01/17				7.6		900	8.0	1020	47.0	9.1	149.0	2.7	0.11	121.0	240.0	19.0	0.3	527	
110	SW18	B	250.6	1793.2	90/02/16				6.8		1300	7.2	1500	57.0	13.0	210.0	3.8	0.60	131.0	350.0	27.0	0.4	726	
111	SW18	B	249.9	1789.2	90/03/13				7.0		2200	7.0	2850	74.0	23.0	400.0	5.6	0.13	132.0	728.0	37.0	0.8	1130	
112	SW18	B	250.5	1796.9	90/04/09				7.0		1800	7.1	2110	57.0	21.0	305.0	3.7	0.21	127.0	542.0	35.0	0.0	1030	

Table1.3.2 Montly monitoring water levels and chemical compositions of groundwater and surface water in Chonnabot Hydrogeologic Province (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL m	ELA m	HEAD m	FpH	FTEMP °C	FEc µS	LpH	LEc µS	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	TDS mg/l	TDSEVP mg/l
113	WW13	B	243.4	1792.6	89/11/06	16.90	214.00	197.10	7.3		800	8.1	738	80.0	20.0	60.0	2.7	0.03	478.0	10.0	2.1	0.0	410	
114	WW13	B	243.4	1792.6	89/12/00		214.00																	
115	WW13	B	243.4	1792.6	90/01/19	17.52	214.00	196.48	6.7		600	7.4	725	80.0	18.0	57.0	1.7	0.06	484.0	8.7	1.5	0.2	406	488
116	WW13	B	243.4	1792.6	90/02/15	17.80	214.00	196.20	6.8		700	7.1	742	86.0	16.0	58.0	2.3	0.00	489.0	11.0	3.5	0.0	417	400
117	WW13	B	243.4	1792.6	90/03/14	17.97	214.00	196.03	6.8		700	7.6	757	84.0	17.0	57.0	1.8	0.00	491.0	13.0	0.0	0.9	416	
118	WW13	B	243.4	1792.6	90/04/09	17.10	214.00	196.90	6.9		600	7.3	719	82.0	17.0	59.0	2.5	0.11	477.0	11.0	1.9	0.5	409	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL m	ELA m	HEAD m	FpH	FTEMP °C	FEc µS	LpH —	LEc µS	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	TDS mg/l	TDSEVP mg/l
1	P83	C	270.5	1811.4	89/03/00		141.9																	
2	P83	C	270.5	1811.4	89/04/08		141.9																	
3	P83	C	270.5	1811.4	89/05/11		141.9																	
4	P83	C	270.5	1811.4	89/06/09	6.20	141.9	135.70	6.0		19900	6.6	150000	520.0	388.0	48000.0	290.0	0.26	145.0	76400.0	4490.0	74.0	130000	
5	P83	C	270.5	1811.4	89/07/12	5.78	141.9	136.12	6.5	27.0	19900	6.5	144000	2840.0	231.0	49200.0	210.0	5.30	144.0	75600.0	3640.0	107.0	13200	
6	P83	C	270.5	1811.4	89/08/10	5.04	141.9	136.86	7.5	29.0	19900	6.6	151000	2960.0	219.0	28200.0	179.0	4.80	159.0	74800.0	4360.0	59.0	131000	
7	P83	C	270.5	1811.4	89/09/16	4.60	141.9	137.30	6.9		19900	6.6	154000	2400.0	487.0	50000.0	193.0	3.90	146.0	76200.0	18.0	101.0	129500	
8	P83	C	270.5	1811.4	89/10/20	4.15	141.9	137.75	6.5		19900	6.5	14450	2500.0	377.0	4920.0	212.0	4.30	165.0	75700.0	4130.0	7.0	13200	
9	P83	C	270.5	1811.4	89/11/18	4.31	141.9	137.59	6.6		19900	7.2	14800	2850.0	540.0	5050.0	173.0	4.00	167.0	76800.0	4550.0	0.0	13500	13900
10	P83	C	270.5	1811.4	89/12/00		141.9																	
11	P83	C	270.5	1811.4	90/01/18	5.22	141.9	136.68	6.5		19900	6.8	14500	2460.0	472.0	49800.0	198.0	4.50	170.0	75600.0	4430.0	0.0	133000	137000
12	P83	C	270.5	1811.4	90/02/17		141.9																	
13	P83	C	270.5	1811.4	90/03/18		141.9																	
14	P84	C	268.9	1808.9	89/03/00		143.92																	
15	P84	C	268.9	1808.9	89/04/09	3.15	143.92	140.77																
16	P84	C	268.9	1808.9	89/05/11	3.09	143.92	140.83	7.6		560	6.9	399	15.0	1.2	68.0	1.7	3.70	201.0	20.0	2.1	0.0	208	
17	P84	C	268.9	1808.9	89/06/09	2.95	143.92	140.97	7.3		400	6.9	402	20.0	2.7	67.0	2.0	1.50	193.0	27.0	0.0	0.3	214	
18	P84	C	268.9	1808.9	89/07/13	2.83	143.92	141.09	6.5	30.4	400	6.7	315	18.0	0.5	53.0	1.8	1.30	181.0	13.0	0.0	0.7	176	
19	P84	C	268.9	1808.9	89/08/11	2.64	143.92	141.28	7.7	30.7	300	7.0	292	20.0	0.4	42.0	2.7	0.64	168.0	11.0	0.5	0.0	159	
20	P84	C	268.9	1808.9	89/09/16	2.53	143.92	141.39	8.1		300	6.8	256	18.0	1.2	35.0	1.9	0.38	138.0	7.5	0.0	0.3	132	
21	P84	C	268.9	1808.9	89/10/20	2.51	143.92	141.41	7.3		800	8.0	278	18.0	2.3	40.0	1.4	0.49	154.0	17.0	1.1	0.0	155	
22	P84	C	268.9	1808.9	89/11/18	2.41	143.92	141.51	7.7		400	7.5	286	20.0	1.9	41.0	1.3	0.44	150.0	22.0	4.2	0.3	164	192
23	P84	C	268.9	1808.9	89/12/00		143.92																	
24	P84	C	268.9	1808.9	90/01/18	3.03	143.92		6.8		400	7.0	296	17.0	3.1	35.0	1.3	1.40	156.0	9.1	0.0	1.3	144	156
25	P84	C	268.9	1808.9	90/02/17	3.23	143.92	140.69	6.4		300	7.4	304	19.0	1.7	39.0	1.3	1.60	151.0	16.0	0.0	1.2	152	
26	P84	C	268.9	1808.9	90/03/15	3.34	143.92	140.58	7.0		400	6.9	274	20.0	2.1	36.0	1.2	0.17	159.0	9.1	0.0	1.3	148	
27	P85	C	311.0	1770.4	89/03/00		141.51																	
28	P85	C	311.0	1770.4	89/04/09	5.61	141.51	135.90																
29	P85	C	311.0	1770.4	89/05/11	5.62	141.51	135.89	7.2		1990	6.6	16800	232.0	316.0	2950.0	18.0	2.00	78.0	5120.0	1450.0	0.0	10100	
30	P85	C	311.0	1770.4	89/06/09	5.43	141.51	136.08	7.0		11200	6.9	15900	596.0	56.0	2950.0	18.0	2.90	136.0	4700.0	1470.0	2.1	9860	
31	P85	C	311.0	1770.4	89/07/13	5.49	141.51	136.02	7.6		14400	6.8	14900	552.0	37.0	2840.0	15.0	1.10	60.0	4440.0	1400.0	3.6	9310	
32	P85	C	311.0	1770.4	89/08/11	5.30	141.51	136.21	8.6		13200	6.5	15000	460.0	134.0	2850.0	18.0	1.00	54.0	4940.0	1340.0	2.0	9770	
33	P85	C	311.0	1770.4	89/09/16	5.21	141.51	136.30	7.7		14200	6.7	15500	540.0	46.0	2780.0	18.0	1.40	51.0	4490.0	1210.0	0.0	9100	
34	P85	C	311.0	1770.4	89/10/20	5.34	141.51	136.17	6.6		12400	7.2	14600	432.0	122.0	2760.0	13.0	1.10	60.0	4540.0	1270.0	1.0	9160	
35	P85	C	311.0	1770.4	89/11/18	5.26	141.51	136.25	7.6		14300	7.1	14700	536.0	68.0	2800.0	14.0	0.53	56.0	4640.0	1500.0	0.6	9590	10200
36	P85	C	311.0	1770.4	89/12/00		141.51																	
37	P85	C	311.0	1770.4	90/01/18	5.65	141.51	135.86	6.5		11200	6.7	15200	464.0	88.0	2790.0	10.0	2.80	58.0	4590.0	1360.0	1.3	9330	9760
38	P85	C	311.0	1770.4	90/02/17	5.78	141.51	135.73	6.8		9200	7.4	14500	544.0	44.0	2830.0	10.0	2.00	61.0	4360.0	1340.0	1.1	9160	9560
39	P85	C	311.0	1770.4	90/03/15	5.91	141.51	135.60	7.1		9200	6.9	14200	472.0	88.0	3120.0	10.0	0.49	65.0	4590.0	1580.0	0.6	9880	
40	B1059	C	254.6	1782.5	89/03/18	1.63	160.00	158.37	8.4		3500	7.6	3270	174.0	35.0	444.0	8.2	1.80	269.0	812.0	226.0	0.0	1830	0
41	B1059	C	254.6	1782.5	89/04/07	1.57	160.00	158.43			3100	7.1	3160	190.0	42.0	425.0	6.8	0.34	318.0	758.0	230.0	0.4	1810	0
42	B1059	C	254.6	1782.5	89/05/08	1.81	160.00	158.19	0.8		3200	7.3	3320	117.0	79.0	477.0	6.0	0.00	298.0	816.0	224.0	0.2	1870	
43	B1059	C	254.6	1782.5	89/06/08	1.50	160.00	158.50	6.7		3200	7.3	3830	184.0	37.0	561.0	8.6	3.60	264.0	934.0	269.0	0.3	2120	
44	B1059	C	254.6	1782.5	89/07/03	1.42	160.00	158.58		26.7	3700	7.2	3280	183.0	34.0	440.0	7.3	0.59	303.0	804.0	235.0	0.0	1850	
45	B1059	C	254.6	1782.5	89/08/08	0.94	160.00	159.06	6.7	32.8	3800	7.5	3330	177.0	41.0	432.0	7.4	1.10	307.0	782.0	214.0	0.6	1810	
46	B1059	C	254.6	1782.5	89/09/08	1.25	160.00	158.75	7.4	29.5	3600	7.2	3430	184.0	33.0	476.0	23.0	0.69	272.0	823.0	221.0	0.3	1890	
47	B1059	C	254.6	1782.5	89/10/17	1.10	160.00	158.90	7.2		3500	7.2	3330	207.0	24.0	413.0	8.2	2.50	313.0	754.0	216.0	0.9	1780	
48	B1059	C	254.6	1782.5	89/11/15	1.50	160.00	158.50	8.1		3800	7.4	3910	179.0	90.0	525.0	8.3	0.73	267.0	932.0	267.0	0.2	2130	
49	B1059	C	254.6	1782.5	89/12/18	1.98	160.00	158.02	8		3600	7.7	3750	126.0	71.0	563.0	7.1	0.30	267.0	956.0	266.0	0.0	2120	
50	B1059	C	254.6	1782.5	90/01/14	2.23	160.00	157.77	6.7		2900	8.0	3160	165.0	17.0	437.0	5.2	1.70	115.0	803.0	242.0	0.5	1730	
51	B1059	C	254.6	1782.5	90/02/14	2.68	160.00	157.32	6.5		2800													
52	B1059	C	254.6	1782.5	90/03/13	2.52	160.00	157.48	6.5		2700	7.6	3520	199.0	48.0	425.0	5.3	0.06	327.0	741.0	217.0	0.8	1800	
53	B1059	C	254.6	1782.5	90/04/08	2.00	160.00	158.00	7.1		2100	7.7	3110	143.0	56.0	467.0	4.3	0.00	234.0	753.0	257.0	0.0	1800	
54	B1060	C	254.6	1782.5	89/03/19		170.00		8.2		5400	6.8	5080	566.0	109.0	297.0	6.8	1.80	404.0	1470.0	21.0	86.0	2760	
55	B1060	C	253.4	1777.3	89/04/06		170.00		6.9		4800	6.7	5050	534.0	135.0	278.0	7.0	0.31	394.0	1490.0	15.0	94.0	2750	
56	B1060	C	253.4	1777.3	89/05/08		170.00		6.3		5000	6.7	5060	566.0	135.0	258.0	5.6	1.60	411.0	1510.0	14.0	101.0	2790	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
57	B1060	C	253.4	1777.3	89/06/05		170.00		6.4		4700	6.8	5460	622.0	108.0	282.0	6.4	0.93	412.0	1580.0	18.0	86.0	2910	
58	B1060	C	253.4	1777.3	89/07/10		170.00		7.1	31.7	5600	6.8	5310	614.0	107.0	260.0	7.9	0.37	393.0	1490.0	15.0	91.0	2780	
59	B1060	C	253.4	1777.3	89/08/08		170.00		6.7	31.2	5400	6.6	5340	592.0	126.0	258.0	6.5	0.21	394.0	1530.0	15.0	76.0	2800	
60	B1060	C	253.4	1777.3	89/09/08		170.00		7.0	28.2	5300	6.7	5100	596.0	109.0	273.0	7.0	0.00	392.0	1490.0	16.0	65.0	2750	
61	B1060	C	253.4	1777.3	89/10/17		170.00		6.8	28.2	5600	7.0	5390	585.0	92.0	275.0	6.2	0.00	393.0	1490.0	13.0	10.0	2670	
62	B1060	C	253.4	1777.3	89/11/06		170.00		7.1		5500	7.1	5470	579.0	117.0	287.0	5.3	0.06	393.0	1450.0	17.0	119.0	2770	
63	B1060	C	253.4	1777.3	89/12/18		170.00		7.8		5000	7.1	5400	609.0	122.0	324.0	5.7	0.00	384.0	1550.0	17.0	67.0	2880	
64	B1060	C	253.4	1777.3	90/01/14		170.00		6.8		3900	6.8	4890	519.0	127.0	292.0	4.7	0.00	381.0	1380.0	25.0	101.0	2630	
65	B1060	C	253.4	1777.3	90/02/15		170.00		6.7		3400	7.5	5260	578.0	108.0	316.0	6.3	0.10	347.0	1460.0	24.0	120.0	2780	
66	B1060	C	253.4	1777.3	90/03/13		170.00		6.8		3400	6.7	5080	590.0	111.0	275.0	6.3	0.00	393.0	1450.0	23.0	51.0	2700	
67	B1060	C	253.4	1777.3	90/04/09		170.00	171.00	6.9		3000	7.0	4760	564.0	122.0	303.0	3.6	1.50	396.0	1430.0	28.0	107.0	2750	
68	B1118	C	270.7	1787.7	89/03/00		200.00																	
69	B1118	C	270.7	1787.7	89/04/07	8.99	200.00	191.01	6.7		1300	6.7	1230	179.0	30.0	30.0	7.9	1.00	494.0	117.0	4.6	93.0	705	
70	B1118	C	270.7	1787.7	89/05/07	10.03	200.00	189.97	7.0		1200	6.7	1160	173.0	26.0	29.0	6.7	1.70	506.0	98.0	3.1	78.0	664	
71	B1118	C	270.7	1787.7	89/06/04	7.02	200.00	192.98	6.8		1300	6.8	1320	187.0	7.4	36.0	8.5	12.00	517.0	127.0	7.7	96.0	724	
72	B1118	C	270.7	1787.7	89/07/04	8.53	200.00	191.47	6.7	26.7	2300	6.8	1810	261.0	38.0	42.0	11.0	0.79	493.0	239.0	16.0	214.0	1060	
73	B1118	C	270.7	1787.7	89/08/07	5.60	200.00	194.40	6.5	31.2	1900	6.8	1710	245.0	31.0	37.0	9.9	7.00	500.0	205.0	13.0	143.0	930	
74	B1118	C	270.7	1787.7	89/09/15		200.00		6.6		1500	6.6	1450	218.0	27.0	35.0	9.6	0.45	485.0	162.0	9.0	144.0	843	
75	B1118	C	270.7	1787.7	89/10/16	5.47	200.00	194.53	7.3		2200	6.8	2110	297.0	41.0	55.0	12.0	3.10	464.0	294.0	19.0	294.0	1240	
76	B1118	C	270.7	1787.7	89/11/02	6.55	200.00	193.45	7.3		1300	7.9	984	97.0	32.0	33.0	8.8	2.00	192.0	136.0	6.9	91.0	499	800
77	B1118	C	270.7	1787.7	89/12/00		200.00																	
78	B1118	C	270.7	1787.7	90/01/13	12.75	200.00	187.25	7.0		1300	7.2	1460	198.0	31.0	32.0	35.0	0.39	486.0	137.0	6.1	88.0	768	
79	B1118	C	270.7	1787.7	90/02/14	10.47	200.00	189.53	6.8		1200	7.4	1390	177.0	31.0	29.0	8.6	0.64	406.0	148.0	6.5	44.0	644	
80	B1118	C	270.7	1787.7	90/03/12	8.05	200.00	191.95	6.9		1000	7.0	1330	183.0	28.0	30.0	6.4	0.05	471.0	111.0	3.9	105.0	699	
81	B1118	C	270.7	1787.7	90/04/08	7.43	200.00	192.57	6.8		700	6.9	1120	167.0	29.0	31.0	6.2	0.00	479.0	99.0	2.6	151.0	721	
82	D555	C	271.5	1774.6	89/03/17		212.00		7.9		700	6.7	684	105.0	14.0	19.0	6.0	8.40	456.0	11.0	0.5	0.0	380	
83	D555	C	271.5	1774.6	89/04/06		212.00																	
84	D555	C	271.5	1774.6	89/05/07		212.00																	
85	D555	C	271.5	1774.6	89/06/04		212.00																	
86	D555	C	271.5	1774.6	89/07/09		212.00		6.9	26.5	800	6.5	690	107.0	15.0	21.0	5.8	5.50	456.0	8.7	0.0	0.0	381	
87	D555	C	271.5	1774.6	89/08/06		212.00		7.2	28.9	700	6.7	709	108.0	15.0	20.0	5.5	7.90	459.0	9.9	0.0	0.0	384	
88	D555	C	271.5	1774.6	89/09/08		212.00		7.7	27.9	700	7.4	668	107.0	10.0	20.0	5.2	1.60	456.0	10.0	0.0	0.7	378	
89	D555	C	271.5	1774.6	89/10/16		212.00		7.4		700	6.8	719	109.0	13.0	18.0	5.9	1.80	450.0	9.3	0.0	1.9	379	
90	D555	C	271.5	1774.6	89/11/06		212.00		7.4		700	7.0	676	104.0	17.0	20.0	5.1	1.40	454.0	11.0	0.0	0.0	380	
91	D555	C	271.5	1774.6	89/12/17		212.00		7.3		700	7.4	724	105.0	16.0	22.0	5.0	1.80	451.0	9.4	2.5	0.0	382	
92	D555	C	271.5	1774.6	90/01/13		212.00		6.8		600	7.0	732	104.0	15.0	21.0	3.4	1.60	455.0	9.8	1.4	0.0	379	
93	D555	C	271.5	1774.6	90/02/13		212.00		6.8		600	6.8	687	100.0	19.0	20.0	5.9	3.40	452.0	11.0	1.0	0.0	379	
94	D555	C	271.5	1774.6	90/03/11		212.00		6.8		600	7.4	749	99.0	20.0	22.0	4.1	0.00	446.0	11.0	0.0	0.3	376	
95	D555	C	271.5	1774.6	90/04/07		212.00	213.00	6.6		600	7.0	682	102.0	17.0	20.0	4.4	0.06	451.0	9.5	2.2	0.0	376	
96	D65	C	276.5	1775.1	89/03/17	2.93	199.00	196.07	8.1		700	7.1	631	80.0	16.0	35.0	5.1	12.00	430.0	7.9	0.0	0.0	355	
97	D65	C	276.5	1775.1	89/04/06	2.70	199.00	196.30	6.9		500	7.0	614	64.0	14.0	48.0	4.9	10.00	401.0	5.9	1.3	0.0	335	
98	D65	C	276.5	1775.1	89/05/07	3.05	199.00	195.95	7.3		600	7.4	548	54.0	13.0	47.0	4.5	20.00	369.0	4.0	1.5	0.2	306	
99	D65	C	276.5	1775.1	89/06/04	2.59	199.00	196.41	6.9		600	7.0	601	70.0	12.0	48.0	4.8	12.00	405.0	5.1	0.0	0.0	340	
100	D65	C	276.5	1775.1	89/07/09	2.85	199.00	196.15	7.2	27.3	700	7.1	640	87.0	13.0	32.0	5.3	32.00	436.0	5.9	0.3	0.3	359	
101	D65	C	276.5	1775.1	89/08/06	2.85	199.00	196.15	7.5	30.2	700	7.1	657	84.0	15.0	35.0	4.7	11.00	432.0	7.1	0.0	0.3	358	
102	D65	C	276.5	1775.1	89/09/07	2.88	199.00	196.12	7.5	27.2	700	6.9	653	91.0	15.0	29.0	4.9	10.00	441.0	7.1	1.4	0.7	367	
103	D65	C	276.5	1775.1	89/10/13	2.53	199.00	196.47	7.6		700	7.4	678	81.0	17.0	33.0	5.3	12.00	420.0	5.8	0.5	0.2	350	
104	D65	C	276.5	1775.1	89/11/06	2.37	199.00	196.63	7.5		700	7.2	644	87.0	18.0	31.0	4.7	9.70	441.0	7.8	0.0	0.0	366	
105	D65	C	276.5	1775.1	89/12/17	2.48	199.00	196.52	7.4		700	7.4	677	84.0	16.0	34.0	5.2	14.00	439.0	5.9	1.4	0.5	363	
106	D65	C	276.5	1775.1	90/01/13	2.57	199.00	196.43	6.9		500	7.1	643	65.0	17.0	47.0	2.6	6.10	403.0	5.5	0.0	0.0	335	
107	D65	C	276.5	1775.1	90/02/13	2.70	199.00	196.30	6.8		500	7.2	615	66.0	17.0	46.0	4.7	4.50	406.0	5.3	0.6	0.4	339	
108	D65	C	276.5	1775.1	90/03/11	2.75	199.00	196.25	7.0		500	7.7	505	23.0	19.0	50.0	3.3	0.21	286.0	5.1	0.9	0.0	242	
109	D65	C	276.5	1775.1	90/04/07	2.46	199.00	196.54	6.8		600	7.5	539	50.0	16.0	45.0	3.7	0.00	319.0	5.1	2.2	0.9	280	
110	D739	C	273.7	1787.4	89/03/17	16.66	198.59	181.93	8.2		1000	6.4	976	119.0	22.0	29.0	9.2	0.60	266.0	104.0	1.9	127.0	543	
111	D739	C	273.7	1787.4	89/04/07	8.06	198.59	190.53	6.0		800	6.6	785	94.0	18.0	28.0	6.9	4.70	316.0	60.0	0.8	46.0	410	
112	D739	C	273.7	1787.4	89/05/07	11.94	198.59	186.65	7.1		900	6.5	970	118.0	24.0	33.0	8.5	2.00	280.0	95.0	0.0	100.0	517	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank !!ydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
113	D739	C	273.7	1787.4	89/06/04	8.50	198.59	190.09	6.7		900	6.4	913	111.0	23.0	32.0	8.2	2.80	281.0	89.0	0.8	118.0	523	
114	D739	C	273.7	1787.4	89/07/09	8.18	198.59	190.41	6.1	27.9	1700	6.7	1500	170.0	39.0	50.0	16.0	5.20	244.0	192.0	9.4	318.0	914	
115	D739	C	273.7	1787.4	89/08/06	7.03	198.59	191.56	7.1	29.2	1500	6.6	1350	152.0	36.0	40.0	12.0	1.30	245.0	161.0	5.1	241.0	767	
116	D739	C	273.7	1787.4	89/09/07	6.65	198.59	191.94	7.1	27.8	1200	6.4	1140	142.0	27.0	33.0	11.0	6.60	269.0	135.0	2.5	193.0	676	
117	D739	C	273.7	1787.4	89/10/13	9.62	198.59	188.97	7.4		1400	6.8	1400	158.0	41.0	42.0	14.0	4.90	244.0	163.0	3.6	268.0	809	
118	D739	C	273.7	1787.4	89/11/06	5.61	198.59	192.98																
119	D739	C	273.7	1787.4	89/12/17		198.59																	
120	D739	C	273.7	1787.4	90/01/13	5.75	198.59	192.84																
121	D739	C	273.7	1787.4	90/02/13	5.90	198.59	192.69																
122	D739	C	273.7	1787.4	90/03/00	6.00	198.59	192.59																
123	D739	C	273.7	1787.4	90/04/07	6.12	198.59	192.47																
124	D740	C	279.5	1797.2	89/03/17	5.38	182.00	176.62	8.2		2000	6.8	1960	201.0	54.0	111.0	3.0	1.00	433.0	301.0	23.0	203.0	1110	
125	D740	C	279.5	1797.2	89/04/06	3.87	182.00	178.13	6.3		2000	6.8	2160	210.0	64.0	117.0	3.0	2.00	429.0	337.0	27.0	225.0	1190	
126	D740	C	279.5	1797.2	89/05/07	4.12	182.00	177.88	7.3		2000	6.7	2220	264.0	40.0	126.0	3.3	5.20	422.0	333.0	31.0	250.0	1260	
127	D740	C	279.5	1797.2	89/06/04	3.52	182.00	178.48	6.7		2200	6.8	2320	232.0	58.0	135.0	5.6	2.70	443.0	383.0	44.0	302.0	1380	
128	D740	C	279.5	1797.2	89/07/09	2.96	182.00	179.04	5.9	26.5	2700	6.9	2420	294.0	36.0	130.0	6.6	2.70	431.0	394.0	44.0	325.0	1440	
129	D740	C	279.5	1797.2	89/08/06	3.33	182.00	178.67	6.7	29.9	2600	6.8	2460	303.0	37.0	117.0	4.8	2.10	421.0	394.0	39.0	239.0	1340	
130	D740	C	279.5	1797.2	89/09/07	2.79	182.00	179.21	7.1	28.2	2500	6.7	2370	303.0	41.0	122.0	5.8	7.80	428.0	385.0	33.0	326.0	1430	
131	D740	C	279.5	1797.2	89/10/13	2.39	182.00	179.61	7.4		2600	7.2	2560	299.0	43.0	133.0	8.8	15.00	431.0	395.0	53.0	407.0	1550	
132	D740	C	279.5	1797.2	89/11/06	2.50	182.00	179.50	7.2		2500	7.8	2370	275.0	48.0	129.0	5.6	7.10	351.0	395.0	57.0	287.0	1370	
133	D740	C	279.5	1797.2	89/12/17		182.00					6.8	2360	271.0	43.0	124.0	3.3	0.33	420.0	322.0	31.0	244.0	1250	
134	D740	C	279.5	1797.2	90/01/13	4.70	182.00	177.30	6.8		1500	6.9	2420	262.0	43.0	116.0	4.9	0.38	419.0	328.0	27.0	239.0	1220	
135	D740	C	279.5	1797.2	90/02/13	5.70	182.00	176.30	6.4		1700	6.7	2190	268.0	36.0	109.0	2.2	0.18	420.0	324.0	27.0	220.0	1190	
136	D740	C	279.5	1797.2	90/03/11	11.30	182.00	170.70	7.1		1900	7.6	1820	157.0	37.0	117.0	1.9	0.00	127.0	317.0	23.0	228.0	943	
137	D740	C	279.5	1797.2	90/04/07	10.99	182.00	171.01	6.8		1700	7.2	1770	81.0	115.0	119.0	1.9	0.06	248.0	328.0	32.0	217.0	1020	
138	D839	C	292.1	1795.1	89/03/16	1.70	154.00	152.30	8.1		5500	7.8	5480	60.0	43.0	1030.0	4.2	0.36	530.0	1490.0	150.0	42.0	3080	
139	D839	C	292.1	1795.1	89/04/05	1.63	154.00	152.37	7.0		5400	7.3	5680	60.0	46.0	1090.0	4.2	1.70	534.0	1480.0	147.0	38.0	3130	
140	D839	C	292.1	1795.1	89/05/05	1.49	154.00	152.51	7.0		5400	7.2	5420	68.0	38.0	1140.0	4.2	1.10	536.0	1500.0	98.0	53.0	3160	
141	D839	C	292.1	1795.1	89/06/03	1.20	154.00	152.80	7.2		4800	7.3	5490	60.0	43.0	1000.0	2.4	1.50	523.0	1460.0	102.0	37.0	2960	
142	D839	C	292.1	1795.1	89/07/09	1.09	154.00	152.91	6.1	28.2	6000	7.2	5520	106.0	15.0	1000.0	3.5	0.53	529.0	1460.0	134.0	40.0	3010	
143	D839	C	292.1	1795.1	89/08/06	0.83	154.00	153.17																
144	D839	C	292.1	1795.1	89/09/09	0.80	154.00	153.20	7.1	29.9	6000	7.1	5400	98.0	18.0	1030.0	2.5	1.10	528.0	1510.0	136.0	38.0	3090	
145	D839	C	292.1	1795.1	89/10/13	0.89	154.00	153.11	7.4		5800	8.5	5330	67.0	36.0	993.0	2.2	0.19	378.0	1400.0	99.0	16.0	2830	
146	D839	C	292.1	1795.1	89/11/04	1.06	154.00	152.94	7.3		5600	7.5	5430	70.0	48.0	1090.0	3.2	0.38	528.0	1460.0	111.0	31.0	3080	
147	D839	C	292.1	1795.1	89/12/17	1.52	154.00	152.48	7.9		5400	7.9	5920	80.0	34.0	1080.0	3.5	0.59	522.0	1460.0	139.0	37.0	3100	
148	D839	C	292.1	1795.1	90/01/12	1.57	154.00	152.43	7.2		5000	7.4	5810	70.0	36.0	1040.0	4.4	0.17	527.0	1460.0	142.0	42.0	3060	
149	D839	C	292.1	1795.1	90/02/12	2.25	154.00	151.75	6.9		4200	7.7	5570	70.0	39.0	1010.0	2.7	0.64	523.0	1460.0	140.0	39.0	3020	
150	D839	C	292.1	1795.1	90/03/11	1.83	154.00	152.17	7.0		4300	7.6	5770	72.0	33.0	1020.0	2.6	0.09	524.0	1440.0	131.0	29.0	2990	
151	D839	C	292.1	1795.1	90/04/07	1.50	154.00	152.50	6.5		4200	8.0	5320	77.0	28.0	1200.0	3.1	0.00	531.0	1460.0	143.0	39.0	3210	
152	D842	C	289.4	1802.7	89/03/00		145.00																	
153	D842	C	289.4	1802.7	89/04/05	5.39	145.00	139.61	7.1		3800	7.3	3970	58.0	18.0	812.0	0.6	0.72	780.0	669.0	147.0	233.0	2320	
154	D842	C	289.4	1802.7	89/05/06	5.98	145.00	139.02	7.2		4600	7.2	4780	45.0	38.0	1010.0	0.5	1.30	743.0	1020.0	154.0	189.0	2640	
155	D842	C	289.4	1802.7	89/06/02	5.53	145.00	139.47	7.4		3700	7.3	4130	58.0	14.0	820.0	0.3	1.10	749.0	739.0	134.0	201.0	2340	
156	D842	C	289.4	1802.7	89/07/08	5.38	145.00	139.62	6.0	26.7	4600	7.2	3930	55.0	20.0	814.0	0.5	0.51	741.0	788.0	151.0	170.0	2360	
157	D842	C	289.4	1802.7	89/08/06	5.31	145.00	139.69	6.8	30.2	5100	7.2	4830	72.0	17.0	910.0	0.5	1.00	718.0	1040.0	107.0	57.0	2550	
158	D842	C	289.4	1802.7	89/09/15		145.00		7.1		4700	7.2	4300	70.0	15.0	900.0	0.5	0.58	706.0	950.0	115.0	115.0	2510	
159	D842	C	289.4	1802.7	89/10/13	4.91	145.00	140.09	7.6		4400	7.4	4330	50.0	19.0	1020.0	0.5	1.60	707.0	857.0	101.0	523.0	2920	
160	D842	C	289.4	1802.7	89/11/04	4.95	145.00	140.05																
161	D842	C	289.4	1802.7	89/12/17	5.50	145.00	139.50	7.8		4000	8.2	4240	45.0	20.0	866.0	0.4	1.10	649.0	814.0	138.0	122.0	2330	
162	D842	C	289.4	1802.7	90/01/12	5.65	145.00	139.35	6.9		3400	7.5	3940	49.0	16.0	726.0	0.2	1.00	699.0	675.0	158.0	122.0	2130	
163	D842	C	289.4	1802.7	90/02/12	6.85	145.00	138.15	7.1		3300	7.3	3910	56.0	15.0	763.0	1.2	0.72	691.0	677.0	162.0	154.0	2170	
164	D842	C	289.4	1802.7	90/03/10	6.05	145.00	138.95	7.2		3100	7.5	4100	60.0	8.6	786.0	0.3	0.07	678.0	701.0	128.0	33.0	2050	
165	D842	C	289.4	1802.7	90/04/05	6.54	145.00	138.46	6.9		3200	7.6	4010	50.0	20.0	796.0	0.2	0.00	671.0	722.0	143.0	222.0	2280	
166	D842	C	289.4	1802.7	90/0[illegible]/05	6.90	145.00	138.10	6.9		3200	7.6	4010	50.0	20.0	796.0	0.2	0.00	671.0	722.0	143.0	222.0	2280	
167	D870	C	276.5	1779.3	89/03/18	12.10	179.00	166.90	8.7		1200	6.9	1240	158.0	29.0	55.0	9.0	0.48	463.0	121.0	28.0	110.0	737	
168	D870	C	276.5	1779.3	89/04/06	5.58	179.00	173.42	6.5		1500	6.8	1490	196.0	29.0	55.0	10.0	0.64	461.0	150.0	35.0	139.0	841	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
169	D870	C	276.5	1779.3	89/05/07	10.55	179.00	168.45	6.8		1400	6.8	1440	196.0	28.0	52.0	9.5	1.10	450.0	142.0	30.0	138.0	818	
170	D870	C	276.5	1779.3	89/06/04	10.11	179.00	168.89	6.8		1600	6.9	1720	237.0	32.0	64.0	12.0	1.80	425.0	198.0	40.0	272.0	1060	
171	D870	C	276.5	1779.3	89/07/09	9.62	179.00	169.38	6.8	31.5	2400	7.0	1920	259.0	36.0	64.0	15.0	3.60	436.0	222.0	64.0	333.0	1210	
172	D870	C	276.5	1779.3	89/08/06	9.93	179.00	169.07	7.2	31.3	2300	6.7	2070	277.0	43.0	70.0	15.0	15.00	447.0	268.0	71.0	262.0	970	
173	D870	C	276.5	1779.3	89/09/07	9.69	179.00	169.31	7.2	26.8	2100	6.9	1980	276.0	41.0	69.0	15.0	12.00	489.0	243.0	0.6	233.0	1120	
174	D870	C	276.5	1779.3	89/10/13	9.28	179.00	169.72	7.4		2300	7.0	2170	295.0	31.0	76.0	18.0	3.40	435.0	254.0	80.0	401.0	1370	
175	D870	C	276.5	1779.3	89/11/08	9.65	179.00	169.35	7.3		2700	7.6	2400	289.0	46.0	121.0	23.0	3.80	389.0	426.0	82.0	216.0	1390	
176	D870	C	276.5	1779.3	89/12/17	10.03	179.00	168.97	7.3		2700	6.6	2700	304.0	43.0	126.0	26.0	3.20	370.0	475.0	73.0	193.0	1420	
177	D870	C	276.5	1779.3	90/01/13	11.02	179.00	167.98	6.7		1900	7.1	2360	270.0	50.0	130.0	15.0	9.90	805.0	325.0	78.0	120.0	1390	
178	D870	C	276.5	1779.3	90/02/13	11.06	179.00	167.94	6.5		1600	6.5	2020	261.0	44.0	69.0	17.0	3.30	422.0	245.0	90.0	190.0	1120	
179	D870	C	276.5	1779.3	90/03/11	11.30	179.00	167.70	7.1		1900	7.0	2160	270.0	21.0	76.0	14.0	0.00	389.0	233.0	57.0	256.0	1120	
180	D870	C	276.5	1779.3	90/04/07	10.99	179.00	168.01	6.8		1700	7.0	1760	277.0	28.0	71.0	13.0	0.00	424.0	251.0	84.0	121.0	1050	
181	D887	C	284.9	1799.1	89/03/15	3.67	150.00	146.33	6.4		5600	7.3	5100	156.0	15.0	1070.0	5.3	0.63	456.0	709.0	682.0	651.0	3470	
182	D887	C	284.9	1799.1	89/04/05	3.30	150.00	146.70	6.8		5600	7.4	5730	142.0	21.0	1130.0	11.0	1.00	293.0	838.0	902.0	367.0	3560	
183	D887	C	284.9	1799.1	89/05/05	3.98	150.00	146.02	7.0		5700	7.5	5550	148.0	13.0	1190.0	11.0	2.50	269.0	857.0	1120.0	459.0	3930	
184	D887	C	284.9	1799.1	89/06/03	3.66	150.00	146.34	7.4		5000	7.6	5650	130.0	13.0	1080.0	9.0	5.30	248.0	857.0	1200.0	349.0	3760	
185	D887	C	284.9	1799.1	89/07/08	3.29	150.00	146.71	6.2	27.6	6800	7.0	5680	154.0	9.7	1140.0	12.0	1.40	256.0	867.0	1630.0	364.0	4300	
186	D887	C	284.9	1799.1	89/08/05	3.28	150.00	146.72	6.8	29.0	6100	7.5	5930	140.0	27.0	1140.0	13.0	2.00	248.0	882.0	1240.0	333.0	3900	
187	D887	C	284.9	1799.1	89/09/15	3.21	150.00	146.79	6.9		6300	7.4	6160	160.0	4.9	1250.0	14.0	0.55	220.0	883.0	1260.0	240.0	3920	
188	D887	C	284.9	1799.1	89/10/13	3.00	150.00	147.00	7.6		6100	7.7	5760	133.0	48.0	1120.0	9.8	0.75	228.0	870.0	1270.0	392.0	3960	
189	D887	C	284.9	1799.1	89/11/17	3.07	150.00	146.93	8.0		6000	8.1	5780	142.0	19.0	1150.0	13.0	1.30	240.0	879.0	1400.0	342.0	4060	
190	D887	C	284.9	1799.1	89/12/17	6.45	150.00	143.55	7.1		5300	7.5	5990	144.0	16.0	1140.0	10.0	2.40	279.0	826.0	1060.0	360.0	3690	
191	D887	C	284.9	1799.1	90/01/12	3.54	150.00	146.46	6.9		4500	7.6	6120	139.0	15.0	1100.0	7.1	1.10	254.0	854.0	1310.0	179.0	3730	
192	D887	C	284.9	1799.1	90/02/12	3.99	150.00	146.01	7.1		4000	7.8	6030	132.0	18.0	1060.0	7.9	1.70	249.0	852.0	1340.0	175.0	3710	
193	D887	C	284.9	1799.1	90/03/10	4.14	150.00	145.86	7.2		5000	7.6	5850	132.0	20.0	1200.0	8.1	0.00	246.0	811.0	1510.0	261.0	4060	
194	D887	C	284.9	1799.1	90/04/05	3.87	150.00	146.13	6.9		4700	7.6	5710	150.0	18.0	1170.0	9.4	0.21	233.0	889.0	1160.0	406.0	3920	
195	D890	C	293.0	1796.4	89/03/16	8.00	152.00	144.00	8.0		800	7.3	706	38.0	3.8	124.0	2.2	0.00	438.0	25.0	0.0	0.3	409	
196	D890	C	293.0	1796.4	89/04/05	5.86	152.00	146.14	6.8		700	7.3	734	39.0	3.6	129.0	2.4	0.02	446.0	26.0	0.3	0.0	420	
197	D890	C	293.0	1796.4	89/05/05		152.00		7.6		600	7.9	703	40.0	3.6	133.0	2.0	0.05	444.0	27.0	0.0	0.1	424	
198	D890	C	293.0	1796.4	89/06/03	7.37	152.00	144.63	7.3		600	7.3	735	42.0	2.9	122.0	2.1	0.00	448.0	25.0	0.0	0.0	415	
199	D890	C	293.0	1796.4	89/07/09		152.00		6.1	30.6	900	7.5	733	47.0	1.4	106.0	2.2	0.00	454.0	25.0	0.0	0.0	404	
200	D890	C	293.0	1796.4	89/08/05	6.60	152.00	145.40	7.9	29.2	900	7.7	732	43.0	3.9	122.0	2.1	0.07	451.0	26.0	0.0	0.3	420	
201	D890	C	293.0	1796.4	89/09/09		152.00		7.3	28.2	800	7.3	713	45.0	2.2	121.0	1.8	0.00	453.0	26.0	0.0	0.8	420	
202	D890	C	293.0	1796.4	89/10/13		152.00		7.6		700	7.3	713	45.0	2.5	120.0	1.5	0.03	454.0	23.0	0.0	0.0	415	
203	D890	C	293.0	1796.4	89/11/04	4.53	152.00	147.47	7.3		700	7.8	708	45.0	2.0	125.0	2.0	0.00	445.0	27.0	0.0	0.0	419	
204	D890	C	293.0	1796.4	89/12/17	5.40	152.00	146.60	7.2		700	7.6	771	44.0	2.7	131.0	2.0	0.00	446.0	26.0	1.1	0.0	426	
205	D890	C	293.0	1796.4	90/01/12	5.86	152.00	146.14	7.0		700	7.4	764	41.0	4.6	128.0	1.8	0.00	446.0	26.0	0.6	0.0	422	
206	D890	C	293.0	1796.4	90/02/12	5.90	152.00	146.10	7.0		600	7.6	727	39.0	4.5	117.0	1.4	0.00	440.0	30.0	0.7	0.0	410	
207	D890	C	293.0	1796.4	90/03/11	6.02	15.20	9.18	6.6		700	8.0	758	42.0	3.1	128.0	1.2	0.05	450.0	37.0	0.0	0.0	433	
208	D890	C	293.0	1796.4	90/04/07	5.28	152.00	146.72	6.4		700	8.2	614	10.0	4.9	128.0	1.4	0.00	360.0	24.0	1.3	0.0	347	
209	D892	C	289.1	1785.2	89/03/17	5.11	151.00	145.89	7.5		4300	6.4	4030	139.0	48.0	612.0	11.0	28.00	185.0	1150.0	118.0	0.0	2170	
210	D892	C	289.1	1785.2	89/04/06	4.30	151.00	146.70	6.7		4200	6.7	4160	132.0	50.0	616.0	12.0	62.00	231.0	1140.0	68.0	0.0	2170	
211	D892	C	289.1	1785.2	89/05/06	4.61	151.00	146.39	6.8		4000	6.5	3820	131.0	49.0	597.0	10.0	66.00	204.0	1120.0	93.0	0.0	2100	
212	D892	C	289.1	1785.2	89/06/04	4.40	151.00	146.60	6.9		3900	7.0	3860	138.0	36.0	583.0	9.6	27.00	241.0	1110.0	46.0	1.4	2050	
213	D892	C	289.1	1785.2	89/07/09	3.61	151.00	147.39	6.1	30.3	4500	7.4	3930	122.0	45.0	570.0	11.0	15.00	248.0	1140.0	23.0	0.8	2030	
214	D892	C	289.1	1785.2	89/08/06	3.99	151.00	147.01	6.8	30.5	4200	6.7	4180	141.0	50.0	591.0	9.4	49.00	236.0	1140.0	96.0	0.0	2150	
215	D892	C	289.1	1785.2	89/09/07	3.71	151.00	147.29	7.5	27.7	4000	7.1	3760	91.0	47.0	606.0	10.0	21.00	176.0	1110.0	25.0	2.3	1980	
216	D892	C	289.1	1785.2	89/10/13	4.03	151.00	146.97	7.5		4600	7.1	4020	130.0	66.0	589.0	8.2	40.00	239.0	1130.0	85.0	0.0	2130	
217	D892	C	289.1	1785.2	89/11/04	3.82	151.00	147.18	7.0		4300	7.0	3950	130.0	55.0	606.0	10.0	43.00	211.0	1150.0	111.0	0.0	2170	
218	D892	C	289.1	1785.2	89/12/17	4.30	151.00	146.70	7.9		4000	8.0	1090	101.0	56.0	629.0	10.0	3.80	190.0	1170.0	34.0	0.0	2090	
219	D892	C	289.1	1785.2	90/01/12	4.55	151.00	146.45	7.1		3700	7.3	4170	83.0	57.0	635.0	7.6	11.00	165.0	1180.0	39.0	0.6	2090	
220	D892	C	289.1	1785.2	90/02/12	4.67	151.00	146.33	6.7		3500	7.9	3970	99.0	59.0	575.0	7.6	30.00	187.0	1160.0	38.0	0.3	2030	
221	D892	C	289.1	1785.2	90/03/11	4.81	151.00	146.19	6.9		3200	7.4	4190	160.0	45.0	636.0	6.4	0.27	239.0	1140.0	127.0	0.4	2230	
222	D892	C	289.1	1785.2	90/04/07	4.67	151.00	146.33	6.5		3200	7.7	3970	154.0	68.0	638.0	9.5	54.00	234.0	1150.0	132.0	0.0	2270	
223	DG16	C	282.4	1805.4	90/06/27	5.10			7.2		400	7.2	539	75.0	3.2	1.2	16.0	1.40	197.0	36.0	8.3	29.0	266	
224	DG17	C	285.1	1799.0	90/06/27	0.88			7.3		100	6.6	130	19.0	1.4	3.5	1.3	0.15	67.0	3.8	3.0	0.0	65	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
225	DG18	C	271.5	1788.3	90/06/27				7.5		200	8.8	317	15.0	7.4	18.0	36.0	0.58	106.0	19.0	3.0	0.0	164	
226	DG19	C	265.4	1787.4	90/06/27	0.76			7.6		100	5.5	45	1.9	2.4	3.9	1.1	1.90	11.0	7.1	6.9	0.0	29	
227	DG9	C	265.3	1805.1	90/06/23	3.43			7.0		100	6.6	71	7.0	0.7	3.0	3.1	0.29	17.0	8.8	1.2	1.1	33	
228	DOH	C	254.7	1852.7	89/03/00		175.00																	
229	DOH	C	254.7	1852.7	89/04/03		175.00		6.9		1200	7.2	1120	71.0	14.0	156.0	2.2	0.37	505.0	84.0	13.0	43.0	631	
230	DOH	C	254.7	1852.7	89/05/03		175.00		6.3		1200	7.1	1120	90.0	21.0	127.0	1.7	0.37	484.0	99.0	12.0	50.0	639	
231	DOH	C	254.7	1852.7	89/06/01		175.00		7.4		900	7.5	902	32.0	5.0	186.0	1.2	0.57	509.0	40.0	13.0	5.1	535	
232	DOH	C	254.7	1852.7	89/07/06		175.00		6.1	26.9	1200	7.1	1080	57.0	8.8	160.0	2.6	3.10	470.0	89.0	16.0	34.0	599	
233	DOH	C	254.7	1852.7	89/08/03		175.00		7.0	32.6	1300	7.4	1200	65.0	13.0	153.0	2.6	1.50	463.0	97.0	14.0	73.0	646	
234	DOH	C	254.7	1852.7	89/09/04		175.00																	
235	DOH	C	254.7	1852.7	89/10/10		175.00		7.1		1000	8.0	865	17.0	5.1	178.0	2.3	3.20	474.0	37.0	11.0	1.4	486	
236	DOH	C	254.7	1852.7	89/11/00		175.00																	
237	DOH	C	254.7	1852.7	89/12/11		175.00		7.7		1200	7.3	1300	110.0	22.0	128.0	1.1	0.80	473.0	114.0	13.0	103.0	724	
238	DOH	C	254.7	1852.7	90/01/10		175.00		5.8		1000	7.2	1290	102.0	20.0	127.0	1.1	0.22	475.0	60.0	13.0	85.0	643	
239	DOH	C	254.7	1852.7	90/02/07		175.00		7.1		800	7.6	1040	56.0	9.7	165.0	1.4	0.98	479.0	57.0	14.0	9.2	549	
240	DOH	C	300.3	1814.3	90/03/08		154.00		6.7		800	8.0	928	27.0	3.6	184.0	1.1	0.27	483.0	43.0	13.0	3.8	514	
241	DOH	C	254.7	1852.7	90/04/03		154.00	155.00	7.2		1100	7.7	1180	78.0	20.0	159.0	2.5	0.10	470.0	100.0	16.0	90.0	697	
242	DW75C	C	282.8	1804.4	89/11/17		155.00		7.9		400	7.8	365	52.0	2.1	11.0	3.3	0.06	144.0	38.0	0.0	12.0	190	
243	DW75C	C	282.8	1804.4	89/12/00		155.00																	
244	DW75C	C	282.8	1804.4	90/01/00		155.00					8.2	299	32.0	3.0	11.0	4.1	0.44	87.0	33.0	0.0	9.2	135	
245	DW75C	C	282.8	1804.4	90/02/12		155.00		6.6		300	7.0	304	41.0	2.8	7.9	4.2	0.07	114.0	31.0	0.3	10.0	153	
246	DW75C	C	282.8	1804.4	90/03/11	8.11	155.00	146.89	6.7		300	7.0	356	51.0	3.0	9.8	4.3	0.21	147.0	31.0	0.7	16.0	188	
247	DW75C	C	282.8	1804.4	90/04/07	7.50	155.00	147.50	6.3		400	8.1	385	57.0	2.7	10.0	5.0	0.09	163.0	30.0	0.9	14.0	201	
248	F110	C	260.9	1797.1	89/03/18		168.00	0.00	8.6		800	7.1	733	115.0	9.4	26.0	2.3	0.00	375.0	58.0	1.0	0.2	396	
249	F110	C	260.9	1797.1	89/04/07		168.00		7.2		700	6.9	732	113.0	8.5	26.0	1.7	0.10	375.0	56.0	1.3	0.0	392	
250	F110	C	260.9	1797.1	89/05/07		168.00		9.7		700	7.4	702	116.0	8.2	26.0	2.1	0.00	378.0	57.0	1.4	0.2	396	
251	F110	C	260.9	1797.1	89/06/05		168.00		7.0		700	7.0	755	117.0	8.2	27.0	2.1	0.00	377.0	56.0	2.6	0.6	399	0
252	F110	C	260.9	1797.1	89/07/03		168.00		7.2	29.7	800	7.2	739	117.0	9.3	27.0	1.8	0.00	379.0	59.0	0.0	0.0	402	0
253	F110	C	260.9	1797.1	89/08/07		168.00		7.4	30.4	800	7.1	750	120.0	7.5	24.0	1.8	0.70	378.0	58.0	2.5	1.1	401	0
254	F110	C	260.9	1797.1	89/09/08		168.00		7.4	28.7	800	6.8	743	123.0	4.1	26.0	2.0	0.00	376.0	59.0	3.1	0.7	402	0
255	F110	C	260.9	1797.1	89/10/16		168.00		7.3		800	6.7	785	125.0	5.7	27.0	2.1	0.08	373.0	59.0	3.2	1.3	407	0
256	F110	C	260.9	1797.1	89/12/18		168.00		7.4		700	7.2	749	113.0	11.0	25.0	1.6	0.00	372.0	59.0	2.8	0.0	396	
257	F110	C	260.9	1797.1	90/01/14		168.00		7.2		600	7.7	682	106.0	7.4	25.0	1.2	0.00	338.0	57.0	2.4	0.7	366	
258	F110	C	260.9	1797.1	90/02/14		168.00		7.0		600	8.3	744	116.0	7.7	28.0	1.4	0.11	303.0	55.0	2.3	0.6	379	
259	F110	C	260.9	1797.1	90/03/12		168.00		7.2		700	7.1	816	119.0	7.4	27.0	1.3	0.00	359.0	59.0	2.8	0.5	394	
260	F110	C	260.9	1797.1	90/04/08		168.00	169.00	7.3		600	7.7	750	117.0	9.6	29.0	0.9	0.06	369.0	57.0	2.5	0.2	398	
261	F366	C	263.8	1799.6	89/03/13	6.91	170.00	163.09	6.9		300	6.5	263	36.0	5.8	7.0	2.5	7.10	159.0	6.3	0.0	0.8	137	
262	F366	C	263.8	1799.6	89/04/07	9.35	170.00	160.65	7.0		200	6.4	254	34.0	6.9	7.7	2.1	4.40	162.0	5.9	0.0	0.0	137	
263	F366	C	263.8	1799.6	89/05/08	12.30	170.00	157.70	6.7		200	8.0	246	36.0	5.9	7.2	1.7	5.90	156.0	4.0	0.6	0.0	132	
264	F366	C	263.8	1799.6	89/06/05	7.75	170.00	162.25	6.8		200	6.6	263	38.0	5.0	7.2	1.9	15.00	159.0	3.6	0.3	0.0	134	
265	F366	C	263.8	1799.6	89/07/05	8.59	170.00	161.41	6.4	26.9	300	6.1	245	35.0	5.3	8.4	1.8	6.20	151.0	3.6	0.0	0.8	129	
266	F366	C	263.8	1799.6	89/08/07	6.58	170.00	163.42	7.2	30.6	300	6.2	260	40.0	5.1	8.6	2.1	19.00	167.0	4.0	1.4	0.0	143	
267	F366	C	263.8	1799.6	89/09/08	7.00	170.00	163.00	8.0	26.8	300	7.7	247	37.0	4.1	8.1	2.2	14.00	121.0	10.0	1.2	0.3	122	
268	F366	C	263.8	1799.6	89/10/16	5.71	170.00	164.29	7.4		300	6.6	255	35.0	7.5	7.9	1.5	17.00	165.0	10.0	0.0	0.0	143	
269	F366	C	263.8	1799.6	89/11/15	5.48	170.00	164.52	7.5		300	7.5	253	37.0	7.3	7.3	1.7	12.00	169.0	8.2	0.0	0.0	145	
270	F366	C	263.8	1799.6	89/12/18	6.73	170.00	163.27	7.6		200	7.5	253	36.0	3.5	7.2	1.8	6.40	152.0	3.5	0.0	0.0	127	
271	F366	C	263.8	1799.6	90/01/14	6.40	170.00	163.60	7.2		200	8.2	252	35.0	5.5	6.6	1.1	13.00	156.0	1.7	0.0	0.6	127	
272	F366	C	263.8	1799.6	90/02/14	7.89	170.00	162.11	7.0		200	7.7	259	37.0	5.1	6.6	1.3	9.00	156.0	7.1	0.0	0.0	134	
273	F366	C	263.8	1799.6	90/03/12	13.87	170.00	156.13	7.1		200	7.3	275	39.0	6.2	7.2	1.3	4.30	167.0	5.9	1.1	0.0	143	
274	F366	C	263.8	1799.6	90/04/08	6.78	170.00	163.22	7.2		300	7.1	276	37.0	6.3	7.7	1.7	7.00	166.0	5.4	0.0	0.0	140	
275	F701	C	262.6	1777.6	89/03/18		188.00		8.2		700	6.7	687	91.0	15.0	34.0	4.3	3.80	413.0	28.0	2.4	0.8	378	
276	F701	C	262.6	1777.6	89/04/06		188.00		6.2		700	6.7	680	88.0	15.0	32.0	4.1	3.70	386.0	31.0	1.3	0.2	361	
277	F701	C	262.6	1777.6	89/05/07		188.00		7.2		700	6.8	625	84.0	13.0	31.0	3.6	5.20	383.0	28.0	0.0	2.2	350	
278	F701	C	262.6	1777.6	89/06/04		188.00		6.8		600	6.8	672	90.0	13.0	31.0	3.6	2.80	391.0	28.0	0.8	0.3	360	
279	F701	C	262.6	1777.6	89/07/04		188.00		6.2	28.2	800	6.7	671	90.0	14.0	29.0	4.1	1.40	397.0	28.0	0.7	1.4	363	
280	F701	C	262.6	1777.6	89/08/06		188.00		7.1	33.0	800	6.7	662	86.0	14.0	31.0	4.0	4.40	377.0	31.0	0.0	12.0	363	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB BASIN	LOCAX	LOCAY	DATE	SWL m	ELA m	HEAD m	FpH	FTEMP °C	FEc µS	LpH	LEc µS	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	TDS mg/l	TDSEVP mg/l
281	F701	C	262.6	1777.6	89/09/08		188.00		7.3		700	6.6	635	86.0	13.0	32.0	4.2	8.10	367.0	31.0	0.9	0.3	347	
282	F701	C	262.6	1777.6	89/10/16		188.00		7.5		700	6.8	673	87.0	14.0	21.0	4.2	7.20	368.0	33.0	0.5	1.1	341	
283	F701	C	262.6	1777.6	89/11/06		188.00		7.4		700	7.2	646	87.0	18.0	33.0	3.9	3.50	380.0	35.0	0.0	1.4	366	
284	F701	C	262.6	1777.6	89/12/18		188.00		7.9		700	6.5	687	87.0	16.0	32.0	4.3	2.60	387.0	31.0	0.5	2.1	363	
285	F701	C	262.6	1777.6	90/01/14		188.00		6.5		600	7.2	715	85.0	17.0	32.0	5.8	3.80	388.0	31.0	0.3	2.6	365	
286	F701	C	283.7	1792.7	90/02/13		170.00		6.7		700	6.8	668	88.0	13.0	32.0	3.7	2.10	378.0	33.0	1.0	11.0	368	
287	F701	C	262.6	1777.6	90/03/13		188.00		6.6		700	7.9	697	63.0	27.0	32.0	2.9	0.00	355.0	32.0	1.1	0.8	333	
288	F701	C	262.6	1777.6	90/04/09		188.00		7.0		600	7.3	657	85.0	16.0	32.0	2.9	0.00	355.0	33.0	0.7	0.0	344	
289	F804	C	264.8	1805.6	89/03/13		165.00		7.2		2300	7.1	2120	106.0	23.0	299.0	7.6	3.50	308.0	527.0	66.0	0.0	1180	
290	F804	C	264.8	1805.6	89/04/08	0.37	165.00	164.63	7.0		1900	7.1	2190	119.0	15.0	305.0	6.3	0.33	287.0	533.0	48.0	0.0	1170	
291	F804	C	264.8	1805.6	89/05/08	0.37	165.00	164.63	7.7		2300	7.3	2190	118.0	18.0	315.0	5.4	0.44	312.0	523.0	43.0	0.0	1180	
292	F804	C	264.8	1805.6	89/06/05	0.38	165.00	164.62	7.1		1900	7.1	2180	141.0	3.9	300.0	5.7	0.55	305.0	523.0	43.0	0.3	1170	
293	F804	C	264.8	1805.6	89/07/04	0.37	165.00	164.63	7.2	26.3	2400	7.3	2130	123.0	13.0	291.0	5.7	0.27	303.0	531.0	53.0	1.0	1170	
294	F804	C	264.8	1805.6	89/08/07	0.37	165.00	164.63	6.8	29.7	2300	7.6	2200	138.0	4.4	294.0	6.2	0.69	315.0	519.0	44.0	0.7	1160	
295	F804	C	264.8	1805.6	89/09/08	0.37	165.00	164.63	7.5	27.1	2200	7.4	2230	122.0	10.0	306.0	6.2	0.13	285.0	519.0	42.0	0.5	1150	
296	F804	C	264.8	1805.6	89/10/16	0.37	165.00	164.63	7.6		2300	8.0	2090	118.0	14.0	288.0	4.1	1.30	310.0	503.0	44.0	0.0	1120	
297	F804	C	264.8	1805.6	89/11/18	0.37	165.00	164.63	8.1		2300	7.6	2110	120.0	15.0	296.0	3.8	0.44	300.0	517.0	51.0	0.0	1150	
298	F804	C	264.8	1805.6	89/12/18	5.30	165.00	159.70	7.4		2200	7.6	2330	119.0	14.0	306.0	5.1	0.53	305.0	521.0	47.0	0.7	1160	
299	F804	C	264.8	1805.6	90/01/14	1.73	165.00	163.27	7.0		1800	7.4	2270	122.0	17.0	298.0	3.4	0.99	305.0	496.0	51.0	1.0	1140	
300	F804	C	264.8	1805.6	90/02/14	0.37	165.00	164.63	7.2		1900	7.5	2230	127.0	11.0	334.0	3.7	0.33	308.0	517.0	48.0	1.2	1190	
301	F804	C	264.8	1805.6	90/03/12	9.16	165.00	155.84	7.0		1800	7.2	2190	114.0	15.0	288.0	4.1	0.00	282.0	509.0	57.0	0.0	1130	
302	F804	C	264.8	1805.6	90/04/08	0.37	165.00	164.63	6.8		200	7.4	2220	125.0	13.0	303.0	4.5	0.00	228.0	519.0	48.0	0.5	1130	
303	L798	C	237.5	1791.5	89/03/19	6.02	183.00	176.98	8.4		900	7.0	785	63.0	26.0	63.0	1.2	25.00	207.0	32.0	220.0	0.2	506	
304	L798	C	237.5	1791.5	89/04/10	6.77	183.00	176.23																
305	L798	C	237.5	1791.5	89/05/09	6.73	183.00	176.27	7.0		800	6.7	851	65.0	30.0	64.0	1.2	22.00	201.0	27.0	179.0	0.0	464	
306	L798	C	237.5	1791.5	89/06/05	6.53	183.00	176.47	6.8		800	6.7	821	67.0	29.0	63.0	0.5	13.00	194.0	28.0	203.0	0.2	486	
307	L798	C	237.5	1791.5	89/07/10	6.13	183.00	176.87	7.0	31.0	1000	6.5	807	68.0	29.0	63.0	1.0	44.00	217.0	28.0	194.0	0.5	491	
308	L798	C	237.5	1791.5	89/08/08	6.48	183.00	176.52	6.8	29.0	1000	6.6	829	69.0	28.0	59.0	0.9	36.00	216.0	31.0	208.0	0.3	503	
309	L798	C	237.5	1791.5	89/09/13		183.00		7.3		1000	6.3	820	71.0	28.0	64.0	1.0	25.00	205.0	30.0	193.0	0.5	489	0
310	L798	C	237.5	1791.5	89/10/18	6.16	183.00	176.84	7.0		900	6.6	838	71.0	30.0	66.0	0.5	37.00	208.0	32.0	211.0	0.0	512	
311	L798	C	237.5	1791.5	89/11/06	6.18	183.00	176.82	7.2		1000	7.0	890	37.0	51.0	65.0	0.8	22.00	198.0	31.0	235.0	0.0	518	
312	L798	C	237.5	1791.5	89/12/18	6.49	183.00	176.51	7.6		1000	6.7	869	69.0	33.0	73.0	0.8	56.00	215.0	26.0	229.0	0.0	536	
313	L798	C	237.5	1791.5	90/01/17	6.59	183.00	176.41	6.5		1100	7.4	836	70.0	34.0	69.0	0.6	31.00	209.0	30.0	219.0	6.4	531	
314	L798	C	237.5	1791.5	90/02/16	6.65	183.00	176.35	6.8	0.0	700	6.7	865	69.0	31.0	64.0	0.5	5.70	194.0	28.0	271.0	0.1	559	
315	L798	C	237.5	1791.5	90/03/14	6.63	183.00	176.37	7.1		800	7.0	905	71.0	32.0	67.0	0.6	10.00	236.0	36.0	167.0	0.4	489	
316	L798	C	237.5	1791.5	90/04/10	6.30	183.00	176.70	6.8		900	7.0	829	75.0	34.0	64.0	0.7	45.00	246.0	32.0	231.0	0.0	558	
317	P1	C	269.1	1808.7	89/03/00		153.51																	
318	P1	C	269.1	1808.7	89/04/09	1.37	153.51	152.14																
319	P1	C	269.1	1808.7	89/05/11	1.50	153.51	152.01	6.9		990	7.1	1040	105.0	15.0	98.0	3.7	1.60	365.0	154.0	2.9	0.0	558	
320	P1	C	269.1	1808.7	89/06/09	1.34	153.51	152.17	6.9		1000	7.0	1050	106.0	11.0	88.0	3.7	0.46	366.0	155.0	2.0	0.3	546	
321	P1	C	269.1	1808.7	89/07/09	1.41	153.51	152.10	7.8	30.4	1200	7.0	1030	108.0	9.7	94.0	3.7	0.47	368.0	157.0	2.5	0.7	557	
322	P1	C	269.1	1808.7	89/08/10	1.11	153.51	152.40	9.2	27.6	1200	7.1	1060	112.0	7.1	95.0	4.1	0.31	369.0	164.0	3.6	0.3	568	
323	P1	C	269.1	1808.7	89/09/10	1.20	153.51	152.31	7.6		1100	7.2	1040	94.0	11.0	97.0	4.9	0.00	316.0	151.0	0.0	0.2	514	
324	P1	C	269.1	1808.7	89/10/20	0.82	153.51	152.69	7.0		1000	7.8	956	96.0	9.6	93.0	3.6	0.14	345.0	145.0	2.5	1.0	520	
325	P1	C	269.1	1808.7	89/11/18	0.80	153.51	152.71	7.7		1400	7.6	1220	106.0	13.0	142.0	3.1	0.14	362.0	228.0	6.4	0.0	676	750
326	P1	C	269.1	1808.7	89/12/00		153.51																	
327	P1	C	269.1	1808.7	90/02/17	1.72	153.51	151.79	6.9		900	7.5	1050	103.0	9.5	100.0	2.3	0.76	375.0	159.0	2.9	0.6	562	542
328	P1	C	269.1	1808.7	90/03/15	2.00	153.51	151.51	7.0		1100	7.4	1070	101.0	10.0	110.0	2.0	0.00	384.0	160.0	2.7	0.6	552	
329	P1	C	269.1	1808.7	90/04/11	1.70	153.51	151.81	7.1		900	7.7	1060	99.0	11.0	112.0	2.6	0.00	389.0	150.0	1.7	0.0	568	
330	P2	C	269.4	1809.3	89/03/00		152.37																	
331	P2	C	269.4	1809.3	89/04/09	0.25	152.37	152.12																
332	P2	C	269.4	1809.3	89/05/11		152.37		7.1		970	7.3	980	105.0	7.1	98.0	3.3	0.00	358.0	149.0	2.9	0.0	542	
333	P2	C	269.4	1809.3	89/06/09	0.20	152.37	152.17	7.1		900	6.9	968	97.0	4.8	88.0	3.3	0.60	332.0	141.0	1.5	0.7	501	
334	P2	C	269.4	1809.3	89/07/13	0.18	152.37	152.19	7.6	31.2	1200	7.2	907	61.0	26.0	89.0	4.2	1.50	317.0	135.0	0.8	1.5	474	
335	P2	C	269.4	1809.3	89/08/10	0.00	152.37	152.37	8.8	27.4	1200	7.1	1170	54.0	3.4	161.0	14.0	1.20	154.0	273.0	0.0	1.2	582	
336	P2	C	269.4	1809.3	89/09/16	0.20	152.37	152.17	7.7		1100	7.2	1000	99.0	7.1	87.0	4.0	0.20	304.0	145.0	0.6	3.3	495	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
337	P2	C	269.4	1809.3	89/10/20	0.29	152.37	152.08	7.0		1100	7.5	938	82.0	11.0	96.0	3.9	0.00	306.0	152.0	2.1	1.0	498	
338	P2	C	269.4	1809.3	89/11/18	0.33	152.37	152.04	7.7		1100	6.6	1080	113.0	7.0	101.0	5.5	0.00	374.0	167.0	2.7	0.0	580	554
339	P2	C	269.4	1809.3	89/12/00		152.37																	
340	P2	C	269.4	1809.3	90/01/18	0.55	152.37	151.82	6.9		900	8.1	928	77.0	11.0	104.0	2.9	0.55	282.0	160.0	1.4	0.0	495	
341	P2	C	269.4	1809.3	90/02/17	0.66	152.37	151.71	6.7		900	7.7	997	81.0	11.0	96.0	2.5	2.60	285.0	157.0	3.5	1.3	493	
342	P2	C	269.4	1809.3	90/03/15	0.85	152.37	151.52	7.1		900	8.1	935	89.0	8.3	92.0	2.3	0.00	307.0	149.0	0.0	1.3	493	
343	P2	C	269.4	1809.3	90/04/11	1.30	152.37	151.07	7.5		800	8.2	916	89.0	8.0	102.0	2.9	0.00	311.0	148.0	1.2	2.3	507	
344	P3	C	269.6	1809.3	89/03/00		150.32																	
345	P3	C	269.6	1809.3	89/04/09	-0.37	150.32	150.69																
346	P3	C	269.6	1809.3	89/05/11	-0.37	150.32	150.69	7.2		900	7.1	1010	102.0	8.0	90.0	1.9	0.05	353.0	151.0	0.4	0.0	527	
347	P3	C	269.6	1809.3	89/06/09	0.37	150.32	150.69	6.7		1000	7.4	1030	104.0	2.9	98.0	3.3	0.00	349.0	156.0	2.3	0.6	539	
348	P3	C	269.6	1809.3	89/07/13	0.49	150.32	151.81	6.5	25.4	1000	7.1	1000	96.0	12.0	96.0	2.9	0.00	353.0	156.0	2.5	0.9	540	
349	P3	C	269.6	1809.3	89/08/11	0.37	150.32	151.69	6.3	26.4	1100	6.9	1020	107.0	5.8	92.0	3.8	0.00	358.0	160.0	2.6	0.1	548	
350	P3	C	269.6	1809.3	89/09/16	0.37	150.32	151.69	7.5		1200	7.0	1050	105.0	6.5	99.0	3.7	0.28	330.0	158.0	2.8	0.1	537	
351	P3	C	269.6	1809.3	89/10/20	0.91	150.32	152.23	7.1		1000	8.2	1010	89.0	18.0	103.0	3.2	0.00	354.0	157.0	5.3	0.0	550	
352	P3	C	269.6	1809.3	89/11/18	1.91	150.32	148.41	7.7		1300	7.6	1200	25.0	6.6	227.0	3.2	0.00	318.0	211.0	19.0	0.4	648	688
353	P3	C	269.6	1809.3	89/12/00		150.32																	
354	P3	C	269.6	1809.3	90/01/18	1.18	150.32	149.14	6.9		1000	7.8	1020	98.0	9.5	100.0	2.7	0.00	352.0	162.0	2.7	0.7	549	708
355	P3	C	269.6	1809.3	90/02/17	1.10	150.32	149.22	7.1		900	7.7	1060	102.0	7.6	96.0	2.9	0.00	349.0	154.0	2.1	0.2	538	500
356	P3	C	269.6	1809.3	90/03/15	0.97	150.32	149.35	7.0		900	7.7	1020	102.0	9.0	94.0	2.2	0.00	353.0	152.0	2.3	0.6	537	
357	P3	C	269.6	1809.3	90/04/11	0.94	150.32	149.38	7.0		1100	7.4	1040	106.0	7.1	97.0	2.8	0.00	358.0	154.0	2.2	0.0	546	
358	P4	C	269.9	1809.3	89/03/00		146.05																	
359	P4	C	269.9	1809.3	89/05/11	-0.40	146.05	146.45	7.4		1150	7.6	1190	26.0	4.9	245.0	3.1	0.11	319.0	210.0	18.0	0.3	664	
360	P4	C	269.9	1809.3	89/06/09	0.40	146.05	146.45	6.8		1200	7.3	1250	31.0	3.2	225.0	3.2	0.00	316.0	220.0	22.0	0.3	660	
361	P4	C	269.9	1809.3	89/07/13	-2.60	146.05	148.65	6.6	25.2	1300	8.3	1190	29.0	1.2	219.0	3.0	0.05	276.0	214.0	24.0	0.7	636	
362	P4	C	269.9	1809.3	89/08/11	-2.94	146.05	148.99	7.6	27.7	1300	7.3	1220	32.0	1.2	205.0	3.2	0.00	319.0	220.0	24.0	0.2	642	
363	P4	C	269.9	1809.3	89/09/05	-2.82	146.05	148.87	7.9		1400	7.3	1230	28.0	3.1	234.0	3.5	0.15	300.0	204.0	23.0	0.5	643	
364	P4	C	269.9	1809.3	89/10/20	-3.05	146.05	149.10	7.2		1200	8.0	1170	24.0	6.3	217.0	2.4	0.00	320.0	210.0	20.0	0.0	637	
365	P4	C	269.9	1809.3	89/11/18	3.05	146.05	143.00	7.8		1200	7.6	1030	104.0	8.6	99.0	3.1	0.09	357.0	164.0	3.9	0.5	559	746
366	P4	C	269.9	1809.3	89/12/00		146.05																	
367	P4	C	269.9	1809.3	90/01/18	1.40	146.05	144.65	6.9		1200	8.8	1170	19.0	12.0	230.0	2.4	0.00	258.0	212.0	22.0	0.0	636	
368	P4	C	269.9	1809.3	90/02/17	6.00	146.05	140.05	7.0		1100	7.9	1200	27.0	3.9	217.0	3.4	0.00	316.0	206.0	22.0	0.2	635	618
369	P4	C	269.9	1809.3	90/03/15	1.60	146.05	144.45	7.1		1100	7.4	1220	35.0	0.2	212.0	2.1	0.00	319.0	208.0	21.0	0.0	635	
370	P4	C	269.9	1809.3	90/04/11	0.83	146.05	145.22	6.8		1200	7.6	1270	30.0	3.9	215.0	2.9	0.00	324.0	211.0	20.0	0.3	643	
371	P41	C	265.7	1793.9	89/03/00		195.00																	
372	P41	C	265.7	1793.9	89/04/07	5.50	195.00	189.50																
373	P41	C	265.7	1793.9	89/05/07	6.11	195.00	188.89	6.8		100	6.1	201	21.0	6.5	12.0	1.4	17.00	103.0	7.5	10.0	0.0	109	
374	P41	C	265.7	1793.9	89/06/05	6.08	195.00	188.92	6.8		100	5.8	160	13.0	2.9	11.0	2.4	13.00	40.0	6.7	18.0	29.0	102	
375	P41	C	265.7	1793.9	89/07/03	3.70	195.00	191.30	5.8	31.1	100	5.6	79	4.0	0.1	11.0	1.7	9.70	26.0	9.9	5.1	0.0	44	
376	P41	C	265.7	1793.9	89/08/07	4.16	195.00	190.84	6.7	31.9	100	6.0	42	3.2	0.2	5.8	1.4	1.50	12.0	6.7	1.1	0.2	25	0
377	P41	C	265.7	1793.9	89/09/15	2.40	195.00	192.60	7.2		100	4.8	44	1.0	0.6	5.7	1.7	0.15	14.0	5.5	0.9	0.8	25	0
378	P41	C	265.7	1793.9	89/10/17	1.16	195.00	193.84	7.7		100													0
379	P41	C	265.7	1793.9	89/11/16	1.92	195.00	193.08	7.9		100	6.5	45	1.9	1.9	5.4	1.6	0.50	16.0	9.4	0.0	0.0	28	
380	P41	C	265.7	1793.9	89/12/14		195.00																	
381	P41	C	265.7	1793.9	90/01/14	4.29	195.00	190.71	7.1		100	5.7	81	5.0	0.2	9.0	1.0	15.00	28.0	9.0	0.0	0.0	38	
382	P41	C	265.7	1793.9	90/02/13	6.42	195.00	188.38	6.9		200	5.9	150	12.0	2.3	12.0	2.7	41.00	67.0	13.0	1.2	0.6	77	0
383	P41	C	265.7	1793.9	90/03/12	6.50	195.00	188.50	7.1		100	6.9	186	18.0	1.2	11.0	1.6	14.00	82.0	9.5	0.0	0.0	81	
384	P41	C	265.7	1793.9	90/04/08	6.20	195.00	188.80	6.4		100	6.8	237	22.0	4.7	16.0	2.2	19.00	106.0	17.0	3.6	2.2	120	
385	P42	C	256.2	1794.5	89/03/00		157.00																	
386	P42	C	256.2	1794.5	89/04/07	4.26	157.00	152.74																
387	P42	C	256.2	1794.5	89/05/08	4.70	157.00	152.30	7.7		3000	7.1	2820	82.0	11.0	55.0	2.8	1.30	197.0	254.0	967.0	0.2	1970	
388	P42	C	256.2	1794.5	89/06/08	4.22	157.00	152.78	7.6		2306	7.1	3010	97.0	2.4	530.0	3.1	0.81	207.0	321.0	834.0	0.3	1890	
389	P42	C	256.2	1794.5	89/07/03	4.02	157.00	152.98	7.7	28.3	3600	6.9	3060	111.0	5.4	540.0	4.2	3.70	253.0	311.0	992.0	0.0	2090	
390	P42	C	256.2	1794.5	89/08/08	4.15	157.00	152.85	7.0	29.3	2800	7.3	2610	85.0	5.8	466.0	4.0	1.80	263.0	250.0	690.0	0.5	1630	
391	P42	C	256.2	1794.5	89/09/17	3.97	157.00	153.03	7.4		2700	7.4	2590	92.0	3.9	480.0	3.6	0.74	274.0	245.0	768.0	0.5	1730	
392	P42	C	256.2	1794.5	89/10/17		157.00		7.9		3300	7.7	3010	90.0	12.0	549.0	3.2	0.29	183.0	280.0	878.0	0.0	2040	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL	SUB	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
	NO.	BASIN				m	m	m		°C	μS		μS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
393	P42	C	256.2	1794.5	89/11/16		157.00		7.9		3000	7.7	3000	84.0	19.0	556.0	2.7	4.80	190.0	254.0	899.0	0.0	1910	
394	P42	C	256.2	1794.5	89/12/00		157.00																	
395	P42	C	256.2	1794.5	90/01/14		157.00		7.2		25000	7.9	2740	79.0	11.0	545.0	2.1	0.00	175.0	233.0	924.0	0.3	1880	
396	P42	C	256.2	1794.5	90/02/14		157.00		7.1		2400	8.2	2920	75.0	8.0	603.0	2.3	0.06	161.0	221.0	909.0	0.0	1900	
397	P42	C	256.2	1794.5	90/03/13		157.00		7.0		2200	6.6	3170	61.0	6.8	565.0	2.1	0.16	61.0	279.0	944.0	0.4	1890	
398	P42	C	256.2	1794.5	90/04/08		173.00																	
399	P43	C	258.6	1786.2	89/03/00		173.00																	0
400	P43	C	258.6	1786.2	89/04/07	7.48	173.00	165.52																0
401	P43	C	258.6	1786.2	89/05/07	8.28	173.00	164.72	7.1		600	6.7	616	86.0	7.3	32.0	4.1	1.60	256.0	76.0	1.5	0.0	333	0
402	P43	C	258.6	1786.2	89/06/08	8.29	173.00	164.71	6.5		700	6.6	900	123.0	3.6	46.0	4.4	9.60	333.0	114.0	2.0	0.5	475	0
403	P43	C	258.6	1786.2	89/07/04	8.10	173.00	164.90	6.2	27.7	700	6.4	676	95.0	7.4	29.0	3.5	7.70	289.0	74.0	1.9	1.5	354	0
404	P43	C	258.6	1786.2	89/08/07	8.38	173.00	164.62	6.7	30.5	700	6.4	609	79.0	6.8	30.0	3.5	0.58	236.0	77.0	1.4	0.8	315	0
405	P43	C	258.6	1786.2	89/09/17	8.19	173.00	164.81	7.1		1000	5.9	717	86.0	5.7	45.0	4.0	0.31	226.0	101.0	0.8	0.8	354	
406	P43	C	258.6	1786.2	89/09/17	8.19	173.00	164.81	7.1		1000	5.9	717	86.0	5.7	45.0	4.0	0.31	226.0	101.0	0.8	0.8	354	0
407	P43	C	258.6	1786.2	89/10/17	8.07	173.00	164.93	7.4		600	8.2	600	76.0	6.2	32.0	4.1	0.42	224.0	73.0	0.0	0.0	302	0
408	P43	C	258.6	1786.2	89/11/02	8.18	173.00	164.82	6.4		700	6.7	694	78.0	10.0	37.0	3.8	1.00	262.0	80.0	0.0	2.4	341	314
409	P43	C	258.6	1786.2	89/12/00		173.00																	
410	P43	C	258.6	1786.2	90/01/13	8.33	173.00	164.67	7.0		500	8.2	554	24.0	32.0	31.0	2.6	1.40	210.0	73.0	2.7	0.6	270	
411	P43	C	258.6	1786.2	90/02/12	8.24	173.00	164.76	6.6		600	6.8	768	81.0	5.7	44.0	22.0	7.60	267.0	97.0	0.0	4.9	385	
412	P43	C	258.6	1786.2	90/03/12	8.53	173.00	164.47	6.9		500	6.6	677	77.0	7.6	34.0	3.5	0.00	233.0	77.0	1.4	1.4	317	
413	P43	C	258.6	1786.2	90/04/08	8.23	173.00	164.77	6.8		500	8.6	598	84.0	3.2	33.0	2.9	0.17	228.0	76.0	1.3	1.5	314	
414	P44	C	255.2	1786.6	89/03/00		160.00																	0
415	P44	C	255.2	1786.6	89/04/07	2.04	160.00	157.96																0
416	P44	C	255.2	1786.6	89/05/08	2.52	160.00	157.48	7.2		14400	6.6	18500	1140.0	49.0	3170.0	40.0	0.94	135.0	6820.0	394.0	3.0	11700	0
417	P44	C	255.2	1786.6	89/06/08	2.91	160.00	157.09	6.8		12700	6.6	20200	992.0	117.0	3340.0	57.0	1.50	184.0	6660.0	452.0	4.5	11700	0
418	P44	C	255.2	1786.6	89/07/03	2.12	160.00	157.88	7.0	28.0	19600	7.1	19800	1050.0	141.0	3000.0	46.0	0.80	226.0	6780.0	399.0	0.0	11500	0
419	P44	C	255.2	1786.6	89/08/08	2.12	160.00	157.88	6.6	31.2	18600	6.7	20200	992.0	151.0	3030.0	51.0	2.80	192.0	6740.0	417.0	9.9	11500	0
420	P44	C	255.2	1786.6	89/09/17	2.10	160.00	157.90	7.0		18600	7.6	19900	1060.0	80.0	3170.0	55.0	1.10	260.0	6600.0	346.0	0.5	11400	0
421	P44	C	255.2	1786.6	89/10/17	2.09	160.00	157.91	6.7		17900	6.7	19100	960.0	141.0	3130.0	51.0	0.83	196.0	6410.0	373.0	0.8	11200	
422	P44	C	255.2	1786.6	89/11/15	2.01	160.00	157.99	8.0		17500	7.3	19900	960.0	229.0	3270.0	56.0	0.73	272.0	6680.0	360.0	0.0	11700	
423	P44	C	255.2	1786.6	89/12/00		160.00																	
424	P44	C	255.2	1786.6	90/01/14	2.54	160.00	157.46	6.5		1200	6.9	19400	960.0	141.0	3390.0	38.9	1.40	201.0	6680.0	394.0	1.6	11700	
425	P44	C	255.2	1786.6	90/02/14	2.74	160.00	157.26	6.5		10800	6.7	20700	936.0	175.0	3550.0	44.0	3.00	223.0	6520.0	444.0	0.0	11800	
426	P44	C	255.2	1786.6	90/03/13	2.85	160.00	157.15	5.9		9800	6.9	19300	949.0	157.0	3350.0	47.0	0.11	229.0	6760.0	361.0	0.0	11700	
427	P44	C	255.2	1786.6	90/04/08	2.56	160.00	157.44	6.8		8000	6.8	19400	976.0	253.0	3180.0	52.0	0.09	256.0	6570.0	427.0	0.0	11600	
428	P5	C	269.9	1809.5	89/03/00		145.41																	
429	5	C	269.9	1809.5	89/04/09	1.48	145.41	143.93																
430	P5	C	269.9	1809.5	89/05/11	1.65	145.41	143.76	7.1		1990	6.8	3050	102.0	8.8	480.0	6.7	12.00	188.0	857.0	38.0	0.3	1590	
431	P5	C	269.9	1809.5	89/06/09	1.50	145.41	143.91	7.1		2700	6.8	3140	101.0	12.0	500.0	7.1	1.60	201.0	863.0	18.0	0.5	1600	
432	P5	C	269.9	1809.5	89/07/13	1.33	145.41	144.08	7.9	29.7	3100	7.1	2810	107.0	2.0	445.0	5.9	1.10	200.0	788.0	15.0	3.5	1470	
433	P5	C	269.9	1809.5	89/08/11	0.94	145.41	144.47	7.5	27.7	2200	6.9	1970	61.0	6.8	300.0	6.5	0.56	140.0	526.0	0.7	4.4	974	
434	P5	C	269.9	1809.5	89/09/16	0.96	145.41	144.45	7.7		2600	7.7	2390	57.0	12.0	350.0	9.3	0.63	246.0	582.0	3.5	1.2	1140	
435	P5	C	269.9	1809.5	89/10/20	0.88	145.41	144.53	6.9		2100	6.2	1990	59.0	11.0	308.0	7.8	0.14	21.0	525.0	3.9	81.0	1010	
436	P5	C	269.9	1809.5	89/11/18	0.89	145.41	144.52	7.7		2400	7.1	2100	67.0	5.2	312.0	8.8	0.22	218.0	535.0	5.2	38.0	1080	1370
437	P5	C	269.9	1809.5	89/12/00		145.41																	
438	P5	C	269.9	1809.5	90/01/18	1.52	145.41	143.89	6.6		2300	8.1	2230	65.0	8.3	334.0	4.3	0.48	84.0	583.0	14.0	28.0	1080	1360
439	P5	C	269.9	1809.5	90/02/17	1.74	145.41	143.67	6.9		2000	7.1	2190	65.0	6.6	328.0	4.8	0.72	84.0	579.0	11.0	35.0	1070	
440	P5	C	269.9	1809.5	90/03/15	1.88	145.41	143.53	7.1		1800	7.0	1970	61.0	5.8	292.0	4.6	0.21	88.0	512.0	49.0	36.0	1000	
441	P5	C	269.9	1809.5	90/04/11	1.35	145.41	144.06	7.5		1800	7.6	2160	67.0	12.0	320.0	5.8	1.50	241.0	565.0	12.0	54.0	1150	
442	P52	C	268.9	1779.0	89/03/00		201.00																	
443	P52	C	268.9	1779.0	89/04/06	15.59	201.00	185.41																
444	P52	C	268.9	1779.0	89/05/07	16.33	201.00	184.67	7.2		600	7.0	628	89.0	9.3	30.0	7.7	0.84	396.0	26.0	2.2	0.0	339	
445	P52	C	268.9	1779.0	89/06/04	16.22	201.00	184.78	7.2		600	6.9	680	89.0	13.0	32.0	8.1	0.40	417.0	19.0	9.0	0.0	375	
446	P52	C	268.9	1779.0	89/07/04	16.12	201.00	184.88	6.3	26.5	700	6.9	647	89.0	12.0	28.0	9.1	1.50	397.0	20.0	0.0	0.0	353	
447	P52	C	268.9	1779.0	89/08/06	16.34	201.00	184.66	6.4	29.8	800	6.8	667	99.0	7.5	26.0	8.6	1.30	397.0	30.0	0.3	0.0	366	
448	P52	C	268.9	1779.0	89/09/15	16.27	201.00	184.73	7.0		700	6.9	649	92.0	6.9	28.0	8.6	1.60	397.0	25.0	1.6	1.2	398	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB. BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
449	P52	C	268.9	1779.0	89/10/16	14.02	201.00	185.47	7.7		700	7.3	635	86.0	13.0	29.0	7.8	1.50	394.0	19.0	0.3	0.0	349	
450	P52	C	268.9	1779.0	89/11/16	15.59	201.00	185.41	7.7		700	7.8	648	53.0	34.0	30.0	8.4	1.50	399.0	22.0	0.0	0.0	344	
451	P52	C	268.9	1779.0	89/12/00		201.00																	
452	P52	C	268.9	1779.0	90/01/13	15.52	201.00	185.48	7.0		600	7.6	716	82.0	18.0	34.0	7.7	2.70	399.0	26.0	0.6	3.6	368	
453	P52	C	268.9	1779.0	90/02/13	15.53	201.00	185.47	6.3		500	7.4	766	88.0	15.0	44.0	8.6	3.70	416.0	45.0	1.9	0.4	413	
454	P52	C	268.9	1779.0	90/03/11	15.62	201.00	185.38	7.0		600	7.0	760	91.0	16.0	33.0	8.8	0.00	408.0	36.0	1.6	0.4	387	
455	P52	C	268.9	1779.0	90/04/07	14.97	201.00	186.03	6.6		600	7.2	605	71.0	17.0	24.0	16.0	0.09	329.0	30.0	2.2	1.8	324	
456	P53	C	269.1	1782.3	89/03/00		201.00																	
457	P53	C	269.1	1782.3	89/04/06	6.27	201.00	194.73																
458	P53	C	269.1	1782.3	89/05/07		201.00		7.1		800	7.0	770	82.0	36.0	41.0	3.3	0.12	529.0	15.0	1.2	1.8	441	
459	P53	C	269.1	1782.3	89/06/04		201.00		7.0		800	7.0	826	97.0	31.0	37.0	3.3	0.08	545.0	13.0	0.0	2.6	453	
460	P53	C	269.1	1782.3	89/07/04		201.00		6.9	26.7	900	7.0	832	101.0	31.0	35.0	3.7	0.00	559.0	13.0	0.0	2.0	460	
461	P53	C	269.1	1782.3	89/08/06		201.00		6.6	33.4	900	7.0	861	103.0	31.0	36.0	3.3	0.20	551.0	16.0	0.4	0.2	461	
462	P53	C	269.1	1782.3	89/09/15		201.00		7.0		900	6.8	810	105.0	31.0	36.0	3.3	0.18	563.0	13.0	0.0	3.5	469	
463	P53	C	269.1	1782.3	89/10/16		201.00		7.5		900	7.5	858	103.0	30.0	37.0	3.8	0.10	555.0	4.7	0.0	3.9	455	
464	P53	C	269.1	1782.3	89/11/16		201.00		7.6		900	7.8	798	89.0	33.0	37.0	3.1	0.00	518.0	21.0	0.0	5.7	443	
465	P53	C	269.1	1782.3	89/12/00		201.00																	
466	P53	C	269.1	1782.3	90/01/13		201.00		7.2		700	7.5	849	94.0	33.0	35.0	2.0	0.00	520.0	15.0	1.1	6.8	443	
467	P53	C	269.1	1782.3	90/02/13		201.00		7.0		700	6.8	812	98.0	31.0	34.0	2.9	0.00	534.0	14.0	0.6	1.8	446	
468	P53	C	269.1	1782.3	90/03/11		201.00		7.1		700	7.9	574	27.0	35.0	37.0	2.4	0.00	327.0	15.0	1.1	1.9	279	
469	P53	C	269.1	1782.3	90/04/07		201.00		6.7		700	7.4	768	93.0	31.0	38.0	2.6	0.17	532.0	13.0	1.5	33.0	474	
470	P6	C	268.6	1809.3	89/03/00		152.26																	
471	P6	C	268.6	1809.3	89/04/09	1.17	152.26	151.09																
472	P6	C	268.6	1809.3	89/05/11	1.25	152.26	151.01	7.0		850	7.1	845	100.0	7.7	76.0	3.8	0.23	358.0	102.0	0.0	0.0	465	
473	P6	C	268.6	1809.3	89/06/09	1.10	152.26	151.16	7.0		800	7.1	860	98.0	2.1	69.0	3.8	0.00	354.0	100.0	2.5	0.5	450	
474	P6	C	268.6	1809.3	89/07/13	1.23	152.26	151.03	6.3	29.7	1000	7.0	847	89.0	7.3	81.0	3.7	0.18	361.0	102.0	1.1	1.0	463	
475	P6	C	268.6	1809.3	89/08/10	0.90	152.26	151.36	9.1	26.2	900	7.2	842	86.0	6.7	78.0	3.7	0.10	345.0	96.0	0.0	0.5	44	
476	P6	C	268.6	1809.3	89/09/16	0.90	152.26	151.36	7.7		900	7.2	852	80.0	6.1	93.0	3.8	0.06	319.0	99.0	0.6	0.0	440	
477	P6	C	268.6	1809.3	89/10/20	0.80	152.26	151.46	7.0		900	8.4	797	77.0	7.8	84.0	2.5	0.00	283.0	96.0	1.4	0.5	421	
478	P6	C	268.6	1809.3	89/11/18	0.80	152.26	151.46	7.0		900	8.4	797	77.0	7.8	84.0	2.5	0.00	283.0	96.0	1.4	0.5	421	
479	P6	C	268.6	1809.3	89/12/00		152.26																	
480	P6	C	268.6	1809.3	90/01/18	1.29	152.26	150.97	6.9		800	7.9	860	91.0	7.9	70.0	2.3	0.86	339.0	102.0	2.0	0.2	442	
481	P6	C	268.6	1809.3	90/02/17	1.50	152.26	150.76	6.9		800	8.2	809	81.0	9.3	70.0	3.3	0.71	310.0	106.0	1.2	0.2	424	
482	P6	C	268.6	1809.3	90/03/15	1.72	152.26	150.54	7.0		700	7.3	832	89.0	7.0	68.0	2.7	0.00	326.0	101.0	1.7	0.3	431	
483	P6	C	268.6	1809.3	90/04/11	1.38	152.26	150.88	7.4		800	7.8	842	93.0	7.5	67.0	3.1	0.00	345.0	102.0	0.9	0.0	442	
484	P7	C	269.0	1808.4	89/03/00		153.30																	0
485	P7	C	269.0	1808.4	89/04/09	2.66	153.30	150.64																
486	P7	C	269.0	1808.4	89/05/11	3.00	153.30	150.30	7.1		980	7.2	990	97.0	7.7	111.0	2.3	0.19	356.0	149.0	2.0	0.0	544	
487	P7	C	269.0	1808.4	89/06/09	2.85	153.30	150.45	7.0		1000	7.0	1050	102.0	7.1	104.0	2.4	0.25	355.0	157.0	2.5	0.0	549	
488	P7	C	269.0	1808.4	89/07/13	2.91	153.30	150.39	6.6		1400	7.2	1120	110.0	6.5	118.0	2.6	0.34	361.0	185.0	4.0	0.0	605	
489	P7	C	269.0	1808.4	89/08/10	2.69	153.30	150.61	8.7		1200	7.7	1120	108.0	5.7	114.0	2.8	0.00	352.0	184.0	2.7	0.0	592	
490	P7	C	269.0	1808.4	89/09/16	2.68	153.30	150.62	7.5		1400	7.5	1340	118.0	6.3	146.0	2.9	0.08	337.0	239.0	4.3	0.4	684	
491	P7	C	269.0	1808.4	89/10/20	2.41	153.30	150.89	7.0		1600	7.5	1620	122.0	12.0	194.0	2.6	0.28	357.0	338.0	7.9	0.0	851	
492	P7	C	269.0	1808.4	89/11/18	2.31	153.30	150.99	8.0		1700	7.5	1610	130.0	14.0	175.0	2.4	0.03	362.0	341.0	4.4	0.0	846	
493	P7	C	269.0	1808.4	89/12/00		153.30																	
494	P7	C	269.0	1808.4	90/01/16	3.15	153.30	150.15	6.8		1800	7.4	2120	160.0	15.0	225.0	1.7	1.90	374.0	465.0	7.6	0.4	1060	
495	P7	C	269.0	1808.4	90/02/17	3.23	153.30	150.07	7.0		1900	7.6	2370	181.0	19.0	255.0	1.9	0.56	371.0	562.0	6.9	0.2	1210	
496	P7	C	269.0	1808.4	90/03/15	3.55	153.30	149.75	6.8		2300	7.4	2480	186.0	22.0	283.0	2.4	0.00	381.0	593.0	5.1	0.0	1280	
497	P7	C	269.0	1808.4	90/04/11	3.13	153.30	150.17	7.5		1900	7.6	2460	191.0	19.0	251.0	2.3	0.00	385.0	596.0	5.8	0.0	1260	
498	P74	C	282.8	1800.1	89/03/00		200.00																	0
499	P74	C	282.8	1800.1	89/04/00		200.00																	0
500	P74	C	282.8	1800.1	89/05/08	10.83	200.00	189.17	6.8		100	6.3	169	21.0	1.2	11.0	2.5	2.10	91.0	5.9	8.1	0.0	95	
501	P74	C	282.8	1800.1	89/06/05	11.58	200.00	188.42	6.7		200	6.4	251	30.0	1.9	14.0	2.1	5.80	100.0	25.0	4.9	0.8	127	0
502	P74	C	282.8	1800.1	89/07/04	10.45	200.00	189.55	6.0	27.0	200	7.9	278	33.0	0.5	23.0	1.8	1.10	89.0	46.0	15.0	1.6	165	
503	P74	C	282.8	1800.1	89/08/07	11.51	200.00	188.49	6.6	29.6	100	5.2	61	5.0	0.4	8.0	1.2	1.10	30.0	4.7	0.7	0.3	85	0
504	P74	C	282.8	1800.1	89/09/17	11.39	200.00	188.61	6.9		100	5.4	72	3.2	1.0	9.6	1.1	0.56	25.0	6.4	4.2	0.3	38	0

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	μS		μS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
505	P74	C	282.8	1800.1	89/10/16	10.01	200.00	189.99	7.2		100	5.6	79	4.8	1.8	7.4	0.8	0.49	30.0	8.5	0.0	0.4	39	
506	P74	C	282.8	1800.1	89/11/16	12.10	200.00	187.90	6.9		0	6.6	96	6.1	1.8	11.0	1.1	0.86	39.0	11.0	1.5	0.5	52	
507	P74	C	282.8	1800.0	89/12/00		200.00																	
508	P74	C	282.8	1800.1	90/01/14	13.00	200.00	187.00	7.1		0	6.7	82	4.2	0.6	12.0	1.2	3.30	37.0	6.2	1.7	1.1	45	
509	P74	C	282.8	1800.1	90/02/14	13.22	200.00	186.78	6.5		100	7.1	111	4.0	1.8	13.0	1.2	3.30	33.0	16.0	2.6	1.4	56	
510	P74	C	282.8	1800.0	90/03/12	13.12	200.00	186.88	7.0		0	6.5	100	5.0	2.3	10.0	1.2	0.63	39.0	10.0	0.7	0.0	49	
511	P74	C	282.8	1800.0	90/04/08	12.14	200.00	187.86	6.6		100	7.5	479	9.1	2.0	75.0	1.9	0.74	40.0	111.0	11.0	0.0	229	
512	P75	C	282.8	1804.4	89/03/00		154.00																	
513	P75	C	282.8	1804.4	89/04/06	5.28	154.00	148.72																
514	P75	C	282.8	1804.4	89/05/05	6.20	154.00	147.80	6.4		5600	6.4	7700	976.0	136.0	344.0	18.0	11.00	131.0	2550.0	6.2	9.5	4110	0
515	P75	C	282.8	1804.4	89/06/05	5.80	154.00	148.20	6.7		6100	6.4	8273	1000.0	136.0	360.0	19.0	7.70	142.0	2670.0	0.0	0.0	4260	
516	P75	C	282.8	1804.4	89/07/08	5.71	154.00	148.29	6.7	28.1	7700	6.3	7290	938.0	135.0	301.0	16.0	4.00	137.0	2470.0	0.7	6.3	3930	
517	P75	C	282.8	1804.4	89/08/05	5.75	154.00	148.25	6.7	28.8	6200	6.6	6160	776.0	175.0	234.0	17.0	4.00	157.0	2000.0	3.4	44.0	3330	
518	P75	C	282.8	1804.4	89/09/15	5.23	154.00	148.77	6.8		6400	6.5	6240	796.0	95.0	232.0	18.0	5.70	139.0	1990.0	1.9	1.0	3200	
519	P75	C	282.8	1804.4	89/10/13		154.00																	
520	P75	C	282.8	1804.4	89/11/17		154.00		8.1		9400	6.6	9270	1220.0	224.0	427.0	19.0	0.16	106.0	3490.0	0.0	0.4	5430	7460
521	P75	C	282.8	1804.4	89/12/00		154.00																	
522	P75	C	282.8	1804.4	90/01/12		154.00		7.3		7300	6.9	10300	1320.0	268.0	438.0	12.0	0.49	99.0	4040.0	0.9	0.2	6130	
523	P75	C	282.8	1804.4	90/02/12		154.00		6.4		7100	6.4	9600	1310.0	170.0	420.0	12.0	9.00	91.0	3590.0	0.9	0.2	5550	6670
524	P75	C	282.8	1804.4	90/03/11	6.29	154.00	147.71	6.6		5400	6.7	8850	1100.0	273.0	382.0	12.0	22.00	92.0	3060.0	1.3	2.0	4880	
525	P75	C	282.8	1804.4	90/04/07	5.98	154.00	148.02	6.8		5600	6.6	8150	1270.0	55.0	383.0	15.0	18.00	98.0	3130.0	2.7	0.0	4900	
526	P75A	C	282.8	1804.4	89/03/00		154.00																	
527	P75A	C	282.8	1804.4	89/04/06	5.24	154.00	148.76																
528	P75A	C	282.8	1804.4	89/05/05	5.87	154.00	148.13	6.8		10200	6.6	16000	1800.0	156.0	1230.0	30.0	0.89	86.0	5460.0	3.5	0.0	8710	
529	P75A	C	282.8	1804.4	89/06/04	5.80	154.00	148.20	6.8		10200	6.6	16000	1800.0	156.0	1230.0	30.0	0.89	86.0	5460.0	3.5	0.0	8710	
530	P75A	C	282.8	1804.4	89/07/08	5.71	154.00	148.29	6.3	26.6	14800	6.2	14200	1720.0	146.0	1080.0	27.0	0.86	87.0	5180.0	1.1	6.8	8200	
531	P75A	C	282.8	1804.4	89/08/05	8.77	154.00	145.23	6.7	26.7	13600	6.4	14500	1760.0	255.0	1140.0	32.0	1.30	88.0	5440.0	1.4	9.9	8680	
532	P75A	C	282.8	1804.4	89/09/15	5.00	154.00	149.00	6.6		13900	6.3	15100	1240.0	423.0	1200.0	31.0	2.40	88.0	5100.0	2.2	5.5	8050	
533	P75A	C	282.8	1804.4	89/10/13	5.06	154.00	148.94	7.1		13200	6.5	14000	1550.0	277.0	1120.0	22.0	2.90	100.0	5220.0	2.1	0.3	8240	
534	P75A	C	282.8	1804.4	89/11/17	5.45	154.00	148.55	7.9		13500													
535	P75A	C	282.8	1804.4	89/12/00		154.00																	
536	P75A	C	282.8	1804.4	90/01/12	5.53	154.00	148.47	7.2		11200	6.7	14700	1750.0	214.0	1250.0	27.0	5.20	102.0	5360.0	3.3	0.8	8660	
537	P75A	C	282.8	1804.4	90/02/12	6.20	154.00	147.80	6.8		8700	6.4	14300	1730.0	175.0	1280.0	27.0	4.30	683.0	5300.0	2.3	0.5	8850	
538	P75A	C	282.8	1804.4	90/03/11	6.21	154.00	147.79	7.1		7500	6.6	13800	1680.0	268.0	1140.0	26.0	2.60	105.0	5000.0	3.7	1.2	8170	
539	P75A	C	282.8	1804.4	90/04/07	6.00	154.00	148.00	6.8		7800	6.6	13000	1670.0	219.0	1210.0	23.0	3.20	114.0	5310.0	5.2	0.0	8500	
540	P77	C	250.7	1789.0	89/03/00		156.00																	
541	P77	C	250.7	1789.0	89/04/00		156.00																	
542	P77	C	250.7	1789.0	89/05/10	4.98	156.00	151.02	7.6		19900	6.8	72800	960.0	1480.0	16600.0	710.0	1.90	169.0	30300.0	626.0	319.0	51000	
543	P77	C	250.7	1789.0	89/06/08	4.69	156.00	151.31	6.8		19900	6.5	71300	1220.0	705.0	16000.0	660.0	1.80	171.0	29700.0	672.0	310.0	49300	
544	P77	C	250.7	1789.0	89/07/03	4.08	156.00	151.92	6.5	27.1	19900	6.5	71100	1400.0	875.0	16300.0	625.0	0.71	175.0	29900.0	835.0	26.0	50000	
545	P77	C	250.7	1789.0	89/08/08	4.27	156.00	151.73	6.8	30.8	19900	6.6	72300	1200.0	970.0	14800.0	607.0	1.70	167.0	28900.0	728.0	25.0	47300	
546	P77	C	250.7	1789.0	89/09/17	4.42	156.00	151.58	7.1		19900	7.1	69800	1220.0	972.0	14200.0	615.0	1.10	169.0	29300.0	810.0	7.5	47200	
547	P77	C	250.7	1789.0	89/10/17	3.54	156.00	152.46	6.9		19900	7.9	72800	1200.0	997.0	16700.0	9.0	1.00	169.0	28600.0	540.0	28.0	48200	
548	P77	C	250.7	1789.0	89/11/16	3.42	156.00	152.58	7.7		19900	6.9	74900	1150.0	997.0	16600.0	503.0	1.00	173.0	28500.0	698.0	0.0	48500	54200
549	P77	C	250.7	1789.0	89/12/00		156.00																	
550	P77	C	250.7	1789.0	90/01/14	4.68	156.00	151.32	6.6		19900	6.8	71000	1150.0	946.0	15900.0	582.0	2.90	172.0	28900.0	749.0	0.4	48300	
551	P77	C	250.7	1789.0	90/02/14	4.96	156.00	151.04	7.0		19900	7.8	70600	1140.0	1110.0	1650.0	779.0	3.40	174.0	2800.0	730.0	0.3	48400	
552	P77	C	250.7	1789.0	90/03/13	4.67	156.00	151.33	6.7		19900	6.6	67800	1180.0	997.0	1580.0	725.0	1.60	155.0	28400.0	799.0	0.0	4800	
553	P77	C	250.7	1789.0	90/04/08	4.80	156.00	-0.10	6.8		19900	7.0	62800	1220.0	944.0	1580.0	459.0	1.40	177.0	29300.0	817.0	0.5	49000	
554	P78	C	255.7	1786.2	89/03/00		160.00																	0
555	P78	C	255.7	1786.2	89/04/07	1.18	160.00	158.82																
556	P78	C	255.7	1786.2	89/04/07	1.18	160.00	158.82																0
557	P78	C	255.7	1786.2	89/05/08	1.35	160.00	158.65	7.0		14900	6.2	20900	2100.0	183.0	2600.0	36.0	1.10	71.0	7410.0	182.0	2.0	13200	
558	P78	C	255.7	1786.2	89/06/08	1.19	160.00	158.81	6.8		13700	6.6	22200	2200.0	219.0	2750.0	42.0	9.20	97.0	7550.0	1090.0	3.4	13900	
559	P78	C	255.7	1786.2	89/07/03	1.12	160.00	158.88	6.3	27.7	19900	6.4	21500	2150.0	73.0	2500.0	47.0	1.70	78.0	7340.0	915.0	0.0	13100	
560	P78	C	255.7	1786.2	89/08/08	1.05	160.00	158.95	6.8	33.2	19900	6.4	21800	2040.0	185.0	2410.0	42.0	1.30	83.0	7510.0	1000.0	5.9	13200	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
561	P78	C	255.7	1786.2	89/09/17	1.13	160.00	158.87	7.0		19900	7.2	22100	2040.0	127.0	2639.0	9.3	1.00	180.0	7270.0	761.0	5.0	12900	
562	P78	C	255.7	1786.2	89/10/17	0.71	160.00	159.29	7.0		19900	6.8	22300	2120.0	88.0	2570.0	50.0	1.50	142.0	7260.0	692.0	0.0	12900	
563	P78	C	255.7	1786.2	89/11/15	0.94	160.00	159.06	7.9		19800	6.9	22800	2020.0	243.0	2610.0	40.0	0.67	150.0	7300.0	677.0	0.5	13100	15400
564	P78	C	255.7	1786.2	89/12/00		160.00																	
565	P78	C	255.7	1786.2	90/01/14	1.62	160.00	158.38	6.6		12800	6.9	21400	2110.0	141.0	2660.0	33.0	2.60	147.0	7280.0	738.0	0.7	13000	
566	P78	C	255.7	1786.2	90/02/14	1.65	160.00	158.35	6.3		10300	6.6	22000	2070.0	136.0	2750.0	38.0	1.70	143.0	7420.0	938.0	0.7	13400	
567	P78	C	255.7	1786.2	90/03/13	1.70	160.00	158.30	6.0		9200	6.7	19300	2060.0	132.0	2580.0	44.0	0.90	156.0	7080.0	925.0	0.5	12900	
568	P78	C	255.7	1786.2	90/04/08	1.44	160.00	158.56	7.2		7300	6.9	20200	2190.0	137.0	2700.0	29.0	0.00	151.0	7050.0	950.0	1.2	13100	
569	P79	C	263.0	1786.9	89/03/00		207.00																	
570	P79	C	263.0	1786.9	89/04/07	6.97	207.00	200.03																
571	P79	C	263.0	1786.9	89/05/07	7.71	207.00	199.29	7.3		700	7.2	653	86.0	18.0	32.0	5.0	1.70	451.0	11.0	0.0	0.0	375	
572	P79	C	263.0	1786.9	89/06/07	7.71	207.00	199.29	6.8		600	7.0	701	90.0	19.0	34.0	5.5	1.30	438.0	17.0	2.7	0.0	384	
573	P79	C	263.0	1786.9	89/07/04	7.45	207.00	199.55	6.3	29.2	800	7.1	686	89.0	18.0	34.0	6.9	0.86	453.0	12.0	0.0	0.0	382	
574	P79	C	263.0	1786.9	89/08/07	7.60	207.00	199.40	6.7	31.9	700	7.0	694	86.0	19.0	31.0	5.8	0.67	445.0	9.9	0.0	0.5	371	
575	P79	C	263.0	1786.9	89/09/15	7.65	207.00	199.35	8.2		700	7.0	662	88.0	17.0	32.0	5.7	1.20	453.0	9.1	0.0	3.0	378	
576	P79	C	263.0	1786.9	89/10/16	7.53	207.00	199.47	7.7		700	7.4	981	86.0	18.0	33.0	6.2	1.60	444.0	7.0	0.4	0.0	369	
577	P79	C	263.0	1786.9	89/11/16	7.64	207.00	199.36	7.9		900	7.2	726	85.0	23.0	47.0	5.9	1.30	501.0	33.0	0.0	0.5	440	596
578	P79	C	263.0	1786.9	89/12/00		207.00																	
579	P79	C	263.0	1786.9	90/01/13	7.85	207.00	199.15	7.2		700	7.4	727	78.0	24.0	36.0	3.8	1.40	445.0	12.0	0.9	2.2	376	370
580	P79	C	263.0	1786.9	90/02/14	8.00	207.00	199.00	6.4		600	6.9	681	84.0	20.0	33.0	6.0	1.20	444.0	12.0	1.2	3.0	377	408
581	P79	C	263.0	1786.9	90/03/12	8.08	207.00	198.92	7.1		600	7.3	726	85.0	22.0	34.0	4.3	0.00	440.0	11.0	0.6	2.6	376	406
582	P79	C	263.0	1786.9	90/04/08	7.85	207.00	199.15	7.4		500	7.3	674	85.0	20.0	33.0	4.6	0.09	412.0	11.0	1.9	0.0	358	
583	P8	C	269.1	1808.4	89/03/00		153.30																	
584	P8	C	269.1	1808.4	89/04/09	1.80	153.30	151.50																
585	P8	C	269.1	1808.4	89/05/11	3.38	153.30	149.92	7.1		71990	7.4	2080	42.0	9.2	430.0	2.3	2.50	381.0	487.0	11.0	0.2	1170	
586	P8	C	269.1	1808.4	89/06/00		153.30																	
587	P8	C	269.1	1808.4	89/07/00		153.30																	
588	P8	C	269.1	1808.4	89/08/10	2.63	153.30	150.67	8.8	27.1	2000	7.6	1980	46.0	8.8	334.0	2.9	0.06	362.0	444.0	8.0	1.2	1020	
589	P8	C	269.1	1808.4	89/09/16	2.62	153.30	150.68	7.6		2800	7.2	9080	300.0	68.0	1590.0	5.3	0.63	498.0	2580.0	34.0	2.8	4820	
590	P8	C	269.1	1808.4	89/10/20	2.33	153.30	150.97	6.9		2400	8.2	2170	50.0	20.0	394.0	2.7	0.46	360.0	517.0	10.0	0.9	1170	
591	P8	C	269.1	1808.4	89/11/18	2.26	153.30	151.04	7.9		6300	7.4	6070	178.0	58.0	970.0	3.8	0.15	460.0	1780.0	21.0	0.0	3240	
592	P8	C	269.1	1808.4	90/01/18	3.05	153.30	150.25	7.0		2300	8.2	2590	41.0	17.0	447.0	1.9	0.00	294.0	636.0	13.0	0.0	1300	
593	P8	C	269.1	1808.4	90/02/17	3.26	153.30	150.04	6.9		2300	7.9	2810	66.0	15.0	468.0	2.0	0.44	358.0	690.0	12.0	1.2	1430	
594	P8	C	269.1	1808.4	90/03/15	3.50	153.30	149.80	6.7		2500	7.7	2860	72.0	18.0	496.0	2.2	0.00	365.0	709.0	12.0	0.8	1490	
595	P8	C	269.1	1808.4	90/04/11	3.08	153.30	150.22	7.3		2300	8.1	3000	66.0	20.0	508.0	2.9	0.11	361.0	734.0	12.0	1.2	1520	
596	P80	C	255.1	1824.8	89/03/00		181.00																	
597	P80	C	255.1	1824.8	89/04/07	10.00	181.00	171.00				-0.1												
598	P80	C	255.1	1824.8	89/05/07	10.00	181.00	171.00	7.5		700	7.1	642	91.0	17.0	31.0	5.0	0.63	430.0	16.0	0.0	0.0	372	
599	P80	C	255.1	1824.8	89/06/08	0.59	181.00	180.41	7.1		600	7.1	982	86.0	19.0	30.0	5.2	0.60	430.0	17.0	1.5	0.6	372	
600	P80	C	255.1	1824.8	89/07/04	5.00	181.00	176.00	6.3	28.2	800	7.1	758	95.0	16.0	40.0	7.3	0.45	432.0	42.0	1.5	0.0	415	
601	P80	C	255.1	1824.8	89/08/07	7.00	181.00	174.00	6.7	31.7	800	7.1	715	93.0	16.0	33.0	6.1	0.47	427.0	23.0	1.3	0.0	382	
602	P80	C	255.1	1824.8	89/09/15	0.14	181.00	180.86	7.2		700	7.0	668	89.0	13.0	31.0	6.8	0.73	421.0	23.0	1.6	1.6	373	
603	P80	C	255.1	1824.8	89/10/16	0.18	181.00	180.82	7.7		700	7.3	705	91.0	14.0	34.0	7.5	1.00	416.0	23.0	0.9	0.7	376	
604	P80	C	255.1	1824.8	89/11/16	7.79	181.00	173.21	8.0		800	7.6	667	89.0	18.0	34.0	6.4	0.70	424.0	25.0	0.0	0.0	382	562
605	P80	C	255.1	1824.8	89/12/00		181.00																	
606	P80	C	255.1	1824.8	90/01/16	1.54	181.00	179.46	7.2		600	7.3	758	84.0	20.0	35.0	4.6	0.94	418.0	22.0	0.0	0.0	371	446
607	P80	C	255.1	1824.8	90/02/14	0.94	181.00	180.06	6.3		600	6.9	724	89.0	17.0	35.0	8.8	3.00	433.0	1.0	1.7	393.0	370	
608	P80	C	255.1	1824.8	90/03/12	0.84	181.00	180.16	7.0		600	7.5	788	92.0	21.0	35.0	6.3	0.00	437.0	24.0	1.1	1.0	396	286
609	P80	C	255.1	1824.8	90/04/08	0.35	181.00	180.65	6.5		600	7.2	745	99.0	16.0	39.0	10.0	0.00	469.0	25.0	2.5	0.6	423	
610	P84	C	268.9	1808.9	89/03/00		155.00																	
611	P84	C	268.9	1808.9	89/04/09	3.15	155.00	151.85																
612	P84	C	268.9	1808.9	89/05/11	3.09	155.00	151.91	7.6		560	6.9	399	15.0	1.2	68.0	1.7	3.70	201.0	20.0	2.1	0.0	208	
613	P84	C	268.9	1808.9	89/06/09	2.95	155.00	152.05	7.3		400	6.9	402	20.0	2.7	67.0	2.0	1.50	193.0	27.0	0.0	0.3	214	
614	P84	C	268.9	1808.9	89/07/13	2.83	155.00	152.17	6.5	30.4	400	6.7	315	18.0	0.5	53.0	1.8	1.30	181.0	13.0	0.0	0.7	176	
615	P84	C	268.9	1808.9	89/08/11	2.64	155.00	152.36	7.7	30.7	300	7.0	292	20.0	0.4	42.0	2.7	0.64	168.0	11.0	0.5	0.0	159	
616	P84	C	268.9	1808.9	89/09/16	2.53	155.00	152.47	8.1		300	6.8	256	18.0	1.2	35.0	1.9	0.38	138.0	7.5	0.0	0.3	132	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB BASIN	LOCAX	LOCAY	DATE	SWL m	ELA m	HEAD m	FpH	FTEMP °C	FEc µS	LpH	LEc µS	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	TDS mg/l	TDSEVP mg/l
617	P84	C	268.9	1808.9	89/10/20	2.51	155.00	152.49	7.3		800	8.0	278	18.0	2.3	40.0	1.4	0.49	154.0	17.0	1.1	0.0	155	
618	P84	C	268.9	1808.9	89/11/18	2.41	155.00	152.59	7.7		400	7.5	286	20.0	1.9	41.0	1.3	0.44	150.0	22.0	4.2	0.3	164	192
619	P84	C	268.9	1808.9	89/12/00		155.00																	
620	P84	C	268.9	1808.9	90/01/18	3.03	155.00	151.97	6.8		400	7.0	296	17.0	3.1	35.0	1.3	1.40	156.0	9.1	0.0	1.3	144	156
621	P84	C	268.9	1808.9	90/02/17	3.23	155.00	151.77	6.4		300	7.4	304	19.0	1.7	39.0	1.3	1.60	151.0	16.0	0.0	1.2	152	
622	P84	C	268.9	1808.9	90/03/15	3.34	155.00	151.66	7.0		400	6.9	274	20.0	2.1	36.0	1.2	0.17	159.0	9.1	0.0	1.3	148	
623	P84	C	268.9	1808.9	90/04/11	2.90	155.00	152.10	7.5		200	7.6	275	22.0	0.6	37.0	1.4	0.63	158.0	8.4	0.0	0.0	147	
624	PWLR	C	269.3	1800.1	89/11/16		201.00		7.8		700	7.6	724	93.0	20.0	40.0	4.8	0.42	472.0	21.0	0.0	0.0	411	
625	PWLR	C	269.3	1800.1	89/12/00		201.00																	
626	PWLR	C	269.3	1800.1	90/01/00		201.00					7.9	705	87.0	20.0	41.0	4.0	0.00	0.0	465.0	190.0	0.2	400	
627	PWLR	C	269.3	1800.1	90/02/14		201.00		6.5		600	8.0	476	25.0	20.0	43.0	3.2	0.14	269.0	19.0	0.0	0.0	241	
628	PWLR	C	269.3	1808.4	90/03/12		201.00		7.1		700	7.5	738	92.0	19.0	40.0	3.4	0.00	481.0	17.0	0.0	0.0	408	
629	PWLR	C	269.3	1808.4	90/04/08		201.00		6.7		800	7.6	727	94.0	18.0	41.0	4.0	0.00	473.0	18.0	1.2	0.0	408	
630	RW10	C	270.0	1805.0	90/06/23				7.0		200	6.3	32	2.4	1.9	1.2	0.5	0.00	16.0	0.0	2.4	0.5	17	
631	RW16	C	282.3	1805.5	90/06/27				6.9		100	8.5	51	8.0	3.3	0.9	0.3	0.88	14.0	8.4	3.0	1.7	38	
632	RW18	C	271.3	1788.2	90/06/27				7.6		100	6.8	31	4.6	0.0	1.0	0.3	1.60	16.0	2.1	0.0	0.0	16	
633	RW19	C	265.5	1787.0	90/06/23				7.6		100	7.8	50	6.6	0.5	1.5	0.7	1.80	22.0	0.4	2.2	3.6	26	
634	RW8	C	259.5	1786.0	90/06/23				7.2		100	8.2	57	7.5	3.5	1.1	1.9	0.37	29.0	5.9	1.0	3.4	38	
635	RW9	C	265.1	1805.4	90/06/23				7.0		100	7.6	59	12.0	1.2	1.1	0.7	0.47	41.0	1.3	0.0	0.0	36	
636	S233	C	271.0	1788.1	89/03/19	5.95	198.65	192.70	8.2		700	6.6	692	101.0	13.0	25.0	4.7	2.80	452.0	9.5	0.5	0.0	376	
637	S233	C	271.0	1788.1	89/04/07	4.45	198.65	194.20	6.6		700	6.7	670	97.0	19.0	26.0	4.5	8.50	451.0	9.1	0.8	1.2	380	
638	S233	C	271.0	1788.1	89/05/07	5.55	198.65	193.10	7.0		700	7.0	674	103.0	18.0	26.0	4.1	2.00	470.0	9.1	0.3	0.0	392	
639	S233	C	271.0	1788.1	89/06/04	5.40	198.65	193.25	6.8		700	6.8	702	104.0	15.0	23.0	4.1	6.90	463.0	9.9	0.0	0.1	384	
640	S233	C	271.0	1788.1	89/07/04	4.46	198.65	194.19	6.4	26.7	800	7.0	690	104.0	15.0	26.0	5.1	10.00	462.0	11.0	1.3	0.0	389	
641	S233	C	271.0	1788.1	89/08/07	5.58	198.65	193.07	6.5	30.2	800	7.0	711	103.0	14.0	23.0	4.5	14.00	451.0	11.0	0.0	0.0	378	
642	S233	C	271.0	1788.1	89/09/15		198.65		6.7		700	6.5	646	102.0	13.0	23.0	4.5	6.20	433.0	9.1	0.0	0.9	366	
643	S233	C	271.0	1788.1	89/10/16	3.98	198.65	194.67	7.4		700	7.0	700	104.0	12.0	24.0	4.9	5.40	450.0	11.0	0.5	0.0	378	
644	S233	C	271.0	1788.1	89/11/02	4.38	198.65	194.27	6.8		700	8.0	372	40.0	11.0	23.0	4.1	1.40	231.0	12.0	0.5	0.0	205	
645	S233	C	271.0	1788.1	89/12/00		198.65																	
646	S233	C	271.0	1788.1	90/01/13	4.72	198.65	193.93	7.0		700	7.1	686	99.0	17.0	23.0	3.2	9.90	442.0	12.0	0.5	0.0	0	
647	S233	C	267.8	1823.1	90/02/17	4.85	198.65	193.80	6.9		600	7.2	608	74.0	17.0	22.0	4.1	11.00	368.0	13.0	1.7	0.3	313	338
648	S233	C	271.0	1788.1	90/03/12	4.92	198.65	193.73	6.8		600	7.1	741	80.0	24.0	25.0	3.4	0.00	416.0	10.0	0.9	0.4	349	
649	S233	C	271.0	1788.1	90/04/15	4.62	198.65	194.03	6.8		400	8.1	302	12.0	17.0	26.0	4.5	11.00	181.0	7.9	1.0	0.0	158	
650	S311	C	259.4	1796.2	89/03/19	0.81	165.00	164.19	9.2		2700	7.8	2590	10.0	7.3	528.0	5.1	0.41	471.0	563.0	53.0	0.2	1400	
651	S311	C	259.4	1796.2	89/04/07	0.83	165.00	164.17	7.8		2600	7.8	2540	1.6	13.0	540.0	5.3	0.32	467.0	553.0	59.0	0.5	1400	
652	S311	C	259.4	1796.2	89/05/07	0.91	165.00	164.09	10.9		3000	7.9	2460	4.8	11.0	537.0	4.3	1.30	466.0	561.0	64.0	0.5	1410	
653	S311	C	259.4	1796.2	89/06/05	0.97	165.00	164.03	7.7		2600	7.9	2620	22.0	1.0	501.0	4.5	2.00	467.0	565.0	75.0	0.7	1400	
654	S311	C	259.4	1796.2	89/07/03	0.86	165.00	164.14	7.8	31.4	3000	7.9	2590	28.0	2.4	480.0	5.7	0.85	474.0	571.0	76.0	1.5	1400	
655	S311	C	259.4	1796.2	89/08/07	0.88	165.00	164.12	6.8	37.2	2900	7.9	2600	11.0	5.8	506.0	5.4	2.90	173.0	570.0	57.0	1.0	1390	
656	S311	C	259.4	1796.2	89/09/08	0.85	165.00	164.15	7.9	29.3	2700	8.0	2510	14.0	3.9	523.0	5.5	4.00	466.0	555.0	71.0	0.7	1400	
657	S311	C	259.4	1796.2	89/10/16	0.81	165.00	164.19	7.9		3200	7.9	2740	13.0	21.0	532.0	5.9	1.90	460.0	546.0	69.0	2.4	1420	
658	S311	C	259.4	1796.2	89/11/02	0.79	165.00	164.21	7.4		2600	8.2	2610	14.0	9.7	565.0	4.5	0.40	467.0	560.0	77.0	0.0	1460	
659	S311	C	259.4	1796.2	89/12/18	0.79	165.00	164.21	7.4		2600	8.0	2680	17.0	25.0	533.0	4.9	0.87	471.0	568.0	66.0	0.2	1450	
660	S311	C	259.4	1796.2	90/01/14	1.04	165.00	163.96	7.2		2200	8.2	2620	11.0	7.0	554.0	3.8	1.10	467.0	545.0	71.0	0.4	1420	
661	S311	C	259.4	1796.2	90/02/14	1.02	165.00	163.98	6.5		2100	8.8	2650	2.9	6.8	560.0	3.9	0.71	387.0	536.0	61.0	0.4	1380	
662	S311	C	259.4	1796.2	90/03/12	1.29	165.00	163.71	6.9		2000	8.0	2860	12.0	11.0	522.0	3.7	0.05	458.0	557.0	59.0	0.4	1390	
663	S311	C	259.4	1796.2	90/04/08	1.00	165.00	164.00	7.3		1700	8.0	2710	12.0	7.3	539.0	4.9	0.14	474.0	550.0	72.0	0.0	1420	
664	S473	C	271.0	1788.1	89/03/00		203.97																	
665	S473	C	271.0	1788.1	89/04/07	9.78	203.97	194.19	7.2		900	6.7	918	137.0	21.0	26.0	6.1	1.80	460.0	58.0	2.0	36.0	512	
666	S473	C	271.0	1788.1	89/05/07	10.03	203.97	193.94	7.2		900	6.8	901	136.0	84.0	25.0	5.3	2.90	465.0	57.0	0.0	6.9	478	
667	S473	C	271.0	1788.1	89/06/04	7.09	203.97	196.88	7.0		900													
668	S473	C	271.0	1788.1	89/07/04	5.05	203.97	198.92																
669	S473	C	271.0	1788.1	89/08/07	5.23	203.97	198.74	6.6	31.3	1100	6.8	1010	146.0	21.0	23.0	7.1	3.10	432.0	81.0	1.9	44.0	536	
670	S473	C	271.0	1788.1	89/09/15		203.97		6.7		1100	6.5	974	149.0	18.0	22.0	7.3	3.10	427.0	81.0	3.4	59.0	550	
671	S473	C	271.0	1788.1	89/10/16	5.28	203.97	198.69	6.7		1100	6.9	1100	148.0	21.0	30.0	9.0	1.40	395.0	118.0	5.6	48.0	573	
672	S473	C	271.0	1788.1	89/11/02	4.68	203.97	199.29	7.0		1000	7.1	980	146.0	23.0	24.0	6.8	2.20	437.0	78.0	2.6	50.0	545	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
673	S473	C	271.0	1788.1	89/12/00		203.97																	
674	S473	C	271.0	1788.1	90/01/13	11.56	203.97	192.41	7.1		900	6.6	1060	143.0	21.0	22.0	4.6	0.97	439.0	76.0	2.0	29.0	514	598
675	S473	C	271.0	1788.1	90/02/14	5.90	203.97	198.07	7.1		800	7.1	758	85.0	22.0	22.0	5.6	2.20	272.0	68.0	2.4	41.0	380	442
676	S473	C	271.0	1788.1	90/03/12	15.03	203.97	188.94	7.0		800	7.0	1020	145.0	11.0	25.0	5.0	0.06	423.0	66.0	1.1	35.0	496	318
677	S473	C	259.4	1796.2	90/04/08	8.94	203.97	195.03	6.9		600	7.5	767	96.0	23.0	24.0	5.3	0.23	314.0	72.0	3.3	0.6	378	
678	S649	C	265.6	1799.4	89/03/13	2.35	171.00	168.65	6.9		700	6.8	631	92.0	12.0	35.0	3.4	4.00	426.0	7.1	2.0	1.3	363	
679	S649	C	265.6	1799.4	89/04/07	2.10	171.00	168.90	6.9		700	6.9	748	106.0	12.0	45.0	2.3	2.80	522.0	7.5	0.8	0.0	430	
680	S649	C	265.6	1799.4	89/05/08	2.43	171.00	168.57	7.0		700	7.4	730	104.0	3.6	42.0	2.7	9.30	503.0	5.5	0.0	0.0	406	
681	S649	C	265.6	1799.4	89/06/05	1.97	171.00	169.03	6.9		600	7.0	700	101.0	9.8	37.0	2.7	8.70	464.0	5.1	0.6	0.0	384	
682	S649	C	265.6	1799.4	89/07/04	2.02	171.00	168.98	6.8	26.3	800	6.7	738	108.0	14.0	37.0	1.9	14.00	512.0	5.9	0.0	0.4	419	
683	S649	C	265.6	1799.4	89/08/07	2.13	171.00	168.87	7.4	29.8	900	7.1	756	108.0	14.0	41.0	3.4	20.00	532.0	6.3	0.0	0.5	435	
684	S649	C	265.6	1799.4	89/09/08	2.23	171.00	168.77	7.4	27.8	800	6.9	781	107.0	15.0	43.0	3.7	5.90	485.0	6.1	0.0	0.0	413	
685	S649	C	265.6	1799.4	89/10/16	1.78	171.00	169.22	7.3		800	6.6	553	102.0	19.0	40.0	2.4	22.00	516.0	4.3	1.9	0.0	424	
686	S649	C	265.6	1799.4	89/11/16	1.63	171.00	169.37	7.9		800	7.1	731	107.0	10.0	39.0	2.2	19.00	490.0	11.0	0.6	0.0	411	
687	S649	C	265.6	1799.4	89/12/18	1.95	171.00	169.05	7.7		800	7.7	804	107.0	17.0	44.0	3.1	12.00	518.0	8.6	0.9	0.3	436	
688	S649	C	265.6	1799.4	90/01/14	2.03	171.00	168.97	7.1		700	8.1	324	6.2	17.0	42.0	2.7	1.90	217.0	8.7	0.0	0.0	184	
689	S649	C	265.6	1799.4	90/02/14	2.22	171.00	168.78	7.2		600	7.5	800	101.0	18.0	38.0	2.1	5.80	487.0	5.2	0.0	0.0	403	
690	S649	C	265.6	1799.4	90/03/12	2.33	171.00	168.67	7.1		700	7.3	749	107.0	15.0	38.0	2.2	0.00	511.0	8.7	0.0	0.0	423	
691	S649	C	265.6	1799.4	90/04/08	2.03	171.00	168.97	7.1		100	7.3	770	107.0	15.0	43.0	2.8	3.50	524.0	11.0	1.2	0.8	438	
692	S722	C	256.4	1773.4	89/03/19	3.50	171.00	167.50	8.3		3900	7.4	3260	210.0	35.0	387.0	3.4	1.10	153.0	681.0	113.0	380.0	1880	
693	S722	C	256.4	1773.4	89/04/06	4.00	171.00	167.00	6.5		2300	7.1	3790	132.0	55.0	381.0	3.1	0.80	640.0	476.0	72.0	15.0	1590	
694	S722	C	256.4	1773.4	89/05/07	4.25	171.00	166.75	7.2		3400	7.0	3480	200.0	103.0	408.0	3.1	2.90	568.0	663.0	124.0	327.0	2110	
695	S722	C	256.4	1773.4	89/06/05	1.41	171.00	169.59	6.9		3720	7.0	4170	318.0	90.0	424.0	3.4	3.50	517.0	804.0	155.0	424.0	2470	
696	S722	C	256.4	1773.4	89/07/04	1.08	171.00	169.92	6.8	28.7	5900	7.1	5220	286.0	176.0	580.0	37.0	0.45	708.0	1090.0	261.0	492.0	3280	
697	S722	C	256.4	1773.4	89/08/08	1.94	171.00	169.06	6.6	30.4	4700	7.0	4360	352.0	71.0	451.0	11.0	0.00	592.0	818.0	153.0	419.0	2570	
698	S722	C	256.4	1773.4	89/09/08	1.10	171.00	169.90	7.2	29.1	5100	7.1	4930	316.0	126.0	521.0	45.0	8.30	588.0	963.0	191.0	299.0	2750	
699	S722	C	256.4	1773.4	89/10/17	0.82	171.00	170.18	6.8		7100	7.0	7320	400.0	217.0	803.0	90.0	1.80	725.0	1420.0	366.0	876.0	4530	
700	S722	C	256.4	1773.4	89/11/06	1.86	171.00	169.14	7.4		5900	7.2	6070	478.0	113.0	613.0	27.0	0.73	546.0	1190.0	283.0	596.0	3570	
701	S722	C	256.4	1773.4	89/12/18	3.03	171.00	167.97	8.0		3600	7.2	3760	295.0	65.0	428.0	3.5	0.10	595.0	686.0	133.0	251.0	2160	
702	S722	C	256.4	1773.4	90/01/14	4.82	171.00	166.18	6.7		2500	7.3	2810	176.0	39.0	369.0	2.8	0.06	628.0	461.0	88.0	199.0	1640	
703	S722	C	256.4	1773.4	90/02/13	8.06	171.00	162.94	7.1		1900	7.2	2530	41.0	60.0	400.0	3.4	0.19	509.0	389.0	77.0	115.0	1340	
704	S722	C	256.4	1773.4	90/03/13	4.09	171.00	166.91	6.6		2600	7.1	3410	221.0	40.0	368.0	2.7	0.00	451.0	569.0	109.0	161.0	1690	
705	S722	C	256.4	1773.4	90/04/09	7.43	171.00	163.57	7.1		2300	7.0	2910	174.0	40.0	373.0	3.8	0.00	470.0	524.0	107.0	138.0	1550	
706	S809	C	260.8	1790.5	89/03/18	0.27	165.00	164.73	8.3		800	7.1	724	70.0	12.0	69.0	5.3	1.00	483.0	10.0	0.5	0.2	410	
707	S809	C	260.8	1790.5	89/04/07	0.50	165.00	164.45	6.8		700	7.2	715	60.0	21.0	69.0	4.4	1.30	486.0	7.9	0.4	0.7	403	
708	S809	C	260.8	1790.5	89/05/07	0.28	165.00	164.72	8.9		700	7.3	693	68.0	19.0	68.0	5.2	4.90	480.0	8.3	1.2	0.0	406	
709	S809	C	260.8	1790.5	89/06/05	0.10	165.00	164.90	7.1		700	7.2	725	72.0	17.0	67.0	5.1	2.60	484.0	6.7	0.0	0.5	406	
710	S809	C	260.8	1790.5	89/07/04	0.28	165.00	164.72	6.4	27.7	800	7.3	716	79.0	13.0	67.0	5.3	1.30	501.0	7.1	0.0	0.0	417	
711	S809	C	260.8	1790.5	89/08/07	0.32	165.00	164.68	6.7	32.5	800	7.2	728	81.0	10.0	63.0	5.0	6.90	484.0	8.3	0.0	0.0	407	
712	S809	C	260.8	1790.5	89/09/07	0.70	165.00	164.30	7.5	29.7	800	7.1	703	71.0	17.0	66.0	4.9	3.00	480.0	7.5	0.0	0.5	403	
713	S809	C	260.8	1790.5	89/10/17	0.71	165.00	164.29	7.6		800	7.5	736	69.0	19.0	68.0	5.4	3.00	478.0	7.0	0.0	0.3	404	
714	S809	C	260.8	1790.5	89/11/15	0.46	165.00	164.54	7.7		800	7.6	659	47.0	20.0	68.0	4.6	2.00	421.0	9.8	0.0	0.0	357	
715	S809	C	260.8	1790.5	89/12/18	1.10	165.00	163.90	7.9		700	7.1	743	67.0	17.0	71.0	5.4	9.40	482.0	8.6	1.6	0.4	408	
716	S809	C	260.8	1790.5	90/01/14	1.79	165.00	163.21	7.1		600	7.4	776	69.0	19.0	67.0	3.1	1.40	482.0	9.4	1.1	0.0	406	
717	S809	C	260.8	1790.5	90/02/13	3.50	165.00	161.50	6.9		600	7.6	732	69.0	19.0	66.0	3.4	1.80	481.0	9.5	1.1	0.4	405	
718	S809	C	260.8	1790.5	90/03/12	3.65	165.00	161.35	6.9		700	8.3	516	13.0	17.0	68.0	3.5	0.00	254.0	9.9	1.0	0.4	251	
719	S809	C	260.8	1790.5	90/04/08	1.76	165.00	163.25	6.8		600	7.8	561	28.0	14.0	65.0	3.9	0.00	298.0	7.1	1.2	1.6	268	
720	SW16	C	254.8	1786.3	89/03/18				10.3		1500	7.2	1280	34.0	7.6	206.0	7.0	0.00	59.0	363.0	1.9	0.0	648	
721	SW16	C	254.8	1786.3	89/04/07				8.4		1500	6.7	1320	30.0	11.0	213.0	6.7	0.40	60.0	373.0	0.7	0.4	664	
722	SW16	C	254.8	1786.3	89/05/08				7.7		1800	6.8	1450	35.0	14.0	224.0	5.6	0.14	88.0	389.0	0.9	0.2	712	
723	SW16	C	254.8	1786.3	89/06/08				7.4		1100	7.0	1190	36.0	7.8	178.0	5.4	1.30	82.0	305.0	1.3	0.9	574	
724	SW16	C	254.8	1786.3	89/07/03				8.2	32.8	1900	6.8	1500	36.0	14.0	225.0	7.4	1.10	88.0	415.0	0.0	0.0	741	
725	SW16	C	254.8	1786.3	89/08/08				6.7	31.7	1600	6.7	1370	38.0	11.0	196.0	6.1	0.08	78.0	377.0	0.0	0.7	667	
726	SW16	C	254.8	1786.3	89/09/17				7.7		2000	7.1	1620	44.0	12.0	254.0	8.0	0.33	78.0	461.0	0.0	0.7	818	
727	SW16	C	254.8	1786.3	89/10/10				7.4		1400	7.5	1340	38.0	16.0	187.0	4.5	0.86	58.0	357.0	9.9	0.6	642	
728	SW16	C	254.8	1786.3	89/11/15				8.0		2200	6.6	2230	57.0	21.0	320.0	5.5	1.10	63.0	6.4	0.0	0.4	1040	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL m	ELA m	HEAD m	FpH	FTEMP °C	FEc µS	LpH	LEc µS	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	TDS mg/l	TDSEVP mg/l
729	SW16	C	254.8	1786.3	89/12/00																			
730	SW16	C	254.8	1786.3	90/01/14				6.5		2100	7.2	2210	58.0	23.0	319.0	5.3	0.11	77.0	615.0	0.9	1.3	1060	
731	SW16	C	254.8	1786.3	90/02/14				6.7		2000	7.6	2280	55.0	22.0	368.0	7.6	0.93	73.0	643.0	1.6	0.4	1130	
732	SW16	C	254.8	1786.3	90/03/13				6.4		1900	7.1	2580	61.0	20.0	370.0	8.1	0.85	72.0	679.0	1.4	1.3	1180	
733	SW16	C	254.8	1786.3	90/04/08				6.8		2000	7.1	2560	62.0	20.0	391.0	9.3	0.75	57.0	738.0	1.2	0.8	1250	
734	SW17	C	256.8	1789.2	89/03/18				8.5		8500	5.3	7950	284.0	85.0	1230.0	47.0	1.40	11.0	2620.0	131.0	0.0	4400	
735	SW17	C	256.8	1789.2	89/04/07				6.8		7800	4.9	8410	296.0	92.0	1280.0	44.0	2.60	8.0	2840.0	144.0	1.0	4730	
736	SW17	C	256.8	1789.2	89/05/08				7.0		11300	5.1	11600	448.0	141.0	1820.0	54.0	4.40	8.0	4110.0	39.0	1.2	6620	
737	SW17	C	256.8	1789.2	89/06/08				7.0		5900	5.5	8070	400.0	27.0	1210.0	42.0	1.50	12.0	2560.0	148.0	3.1	4400	
738	SW17	C	256.8	1789.2	89/07/03				6.9	32.0	11300	5.2	9500	368.0	95.0	1330.0	56.0	2.00	9.0	3110.0	200.0	0.0	5170	
739	SW17	C	256.8	1789.2	89/08/08				7.8	32.4	9100	4.8	8570	310.0	88.0	1190.0	88.0	0.97	7.0	2690.0	141.0	6.2	4480	
740	SW17	C	256.8	1789.2	89/09/17				7.0		11500	5.2	10900	416.0	105.0	1660.0	57.0	1.40	7.0	3520.0	221.0	1.3	5990	
741	SW17	C	256.8	1789.2	89/10/17				7.7		6700	5.6	6800	242.0	67.0	958.0	39.0	0.52	10.0	2010.0	103.0	0.0	3430	
742	SW17	C	256.8	1789.2	89/11/15				8.1		9500	4.8	10100	360.0	118.0	1500.0	59.0	0.50	7.0	3320.0	151.0	5.6	5510	
743	SW17	C	256.8	1789.2	90/01/14				6.6		12700	6.7	17800	800.0	253.0	2940.0	71.0	0.17	79.0	6180.0	361.0	1.7	10650	
744	SW17	C	256.8	1789.2	90/02/14				6.6		14000	4.8	30000	1380.0	399.0	4290.0	92.0	1.60	18.0	10400.0	668.0	2.3	17000	
745	SW17	C	256.8	1789.2	90/03/13				6.3		11600	4.2	26600	1120.0	336.0	4030.0	122.0	0.63	0.0	8500.0	403.0	6.4	14500	
746	SW17	C	256.8	1789.2	90/04/08				6.8		8200	4.3	14700	688.0	204.0	2440.0	56.0	0.00	0.0	5210.0	336.0	4.6	8940	
747	SW22	C	265.2	1809.6	89/03/15		0.00		8.1		1800	8.0	1650	60.0	13.0	247.0	6.3	0.41	135.0	438.0	30.0	0.0	861	
748	SW22	C	265.2	1809.6	89/04/08				7.6		1300	6.7	1930	63.0	18.0	290.0	7.1	0.05	134.0	511.0	28.0	0.2	983	
749	SW22	C	265.2	1809.6	89/05/08		0.00		8.1		2100	7.2	2300	67.0	12.0	356.0	7.4	0.32	125.0	606.0	26.0	0.2	114	
750	SW22	C	265.2	1809.6	89/06/09		0.00		7.2		200	6.8	252	18.0	5.1	16.0	3.8	2.30	65.0	21.0	22.0	0.0	118	
751	SW22	C	265.2	1809.6	89/07/08		0.00		8.8	29.6	400	7.2	319	32.0	5.3	22.0	7.8	1.90	115.0	32.0	21.0	0.8	173	
752	SW22	C	265.2	1809.6	89/08/07		0.00		6.8	28.7	900	7.3	848	31.0	4.5	113.0	5.3	3.70	78.0	209.0	13.0	0.8	416	
753	SW22	C	265.2	1809.6	89/09/16		0.00		8.0		200	7.3	222	18.0	2.8	14.0	2.8	2.10	64.0	17.0	8.4	0.7	94	
754	SW22	C	265.2	1809.6	89/10/20		0.00		7.2		300	7.3	173	16.0	4.7	13.0	1.9	1.40	73.0	17.0	3.7	0.3	93	
755	SW22	C	265.2	1809.6	89/11/16		0.00		8.0		300	7.8	272	22.0	6.9	23.0	1.6	1.30	79.0	51.0	5.2	0.7	149	
756	SW22	C	265.2	1809.6	89/12/17		0.00		7.8		500	7.5	620	28.0	13.0	71.0	2.4	0.10	102.0	132.0	13.0	0.0	309	
757	SW22	C	285.2	1809.6	90/01/18				6.6		800	7.4	990	45.0	10.0	122.0	1.9	0.38	118.0	224.0	18.0	0.0	480	
758	SW22	C	265.2	1809.6	90/02/13		0.00		6.9		1100	7.2	1330	54.0	11.0	182.0	3.7	0.39	136.0	326.0	24.0	0.4	667	
759	SW22	C	265.2	1809.6	90/03/15				7.0		1500	7.2	1740	50.0	26.0	244.0	4.0	0.26	104.0	457.0	28.0	0.2	861	
760	SW22	C	265.2	1809.6	90/04/11				7.4		1700	7.8	1990	55.0	16.0	309.0	4.9	0.15	111.0	546.0	30.0	0.0	1020	
761	SW26	C	270.3	1808.7	89/03/15				8.1		1700	6.8	1530	40.0	13.0	242.0	13.0	0.32	81.0	440.0	0.0	0.2	788	
762	SW26	C	270.3	1808.7	89/04/09				6.9		1400	6.6	1790	45.0	74.0	260.0	16.0	0.59	93.0	477.0	1.3	0.2	859	
763	SW26	C	270.3	1808.7	89/05/05				7.0		1700	6.7	1780	46.0	14.0	272.0	14.0	1.00	93.0	495.0	0.3	0.0	888	
764	SW26	C	270.3	1808.7	89/06/04				7.7		1800	7.0	1860	46.0	13.0	265.0	17.0	0.29	82.0	506.0	0.8	0.0	889	
765	SW26	C	270.3	1808.7	89/07/08				6.2	31.8	2200	6.3	1640	40.0	12.0	230.0	13.0	1.10	59.0	477.0	0.0	0.8	802	
766	SW26	C	270.3	1808.7	89/08/06				6.8	29.3	1900	7.0	1730	43.0	9.4	263.0	15.0	0.56	54.0	490.0	1.4	0.5	851	
767	SW26	C	270.3	1808.7	89/08/15				7.4		1900	6.5	1840	42.0	13.0	288.0	15.0	1.50	47.0	509.0	1.4	0.6	892	
768	SW26	C	270.3	1808.7	89/09/13				7.8		1800	6.5	1650	41.0	19.0	241.0	10.0	0.22	78.0	477.0	1.1	1.3	829	
769	SW26	C	270.3	1808.7	89/10/13				7.8		1800	6.5	1650	41.0	19.0	241.0	10.0	0.22	78.0	477.0	1.1	1.3	829	
770	SW26	C	270.3	1808.7	89/11/17				8.1		1700	7.6	1650	43.0	23.0	243.0	12.0	0.55	72.0	484.0	0.0	0.5	842	
771	SW26	C	270.3	1808.7	89/12/17				7.1		1800	7.7	2080	49.0	20.0	297.0	12.0	0.61	79.0	556.0	1.1	0.5	973	
772	SW26	C	270.3	1808.7	90/01/12				7.6		1700	6.9	2340	60.0	17.0	339.0	9.4	4.90	103.0	627.0	0.0	0.6	1100	
773	SW26	C	270.3	1808.7	90/02/12				6.8		2100	7.0	2560	66.0	17.0	382.0	13.0	1.10	96.0	714.0	1.2	1.9	1240	
774	SW26	C	270.3	1808.7	90/03/11				7.0		2100	7.2	2700	68.0	48.0	380.0	15.0	0.29	98.0	774.0	1.1	0.5	1340	
775	SW26	C	270.3	1808.7	90/04/05				6.8		2100	7.2	2330	61.0	27.0	389.0	14.0	0.69	95.0	683.0	1.2	0.5	1220	
776	SW29	C	265.2	1805.5	90/06/23				7.0		100	7.5	48	2.6	1.4	3.5	3.9	1.60	14.0	2.9	10.0	1.0	32	
777	SW30	C	271.0	1808.0	90/06/23				6.9		100	7.2	458	15.0	3.1	64.0	6.1	7.90	115.0	79.0	5.7	8.5	238	
778	SW35	C	282.4	1805.7	90/06/27				7.1		500	6.8	561	29.0	5.2	62.0	17.0	9.70	75.0	128.0	6.0	0.7	284	
779	SW36	C	285.0	1800.0	90/06/27				7.3		200	7.1	296	10.0	7.5	35.0	12.0	9.10	64.0	39.0	41.0	16.0	191	
780	SW37	C	293.3	1794.5	90/06/27				7.4		800	7.0	873	36.0	6.4	103.0	6.9	8.10	63.0	232.0	4.0	0.5	419	
781	WW16	C	259.4	1786.2	89/03/18	8.79	173.02	164.23	8.2		1100	6.6	858	112.0	19.0	32.0	4.5	40.00	307.0	125.0	1.3	0.0	444	
782	WW16	C	259.4	1786.2	89/04/07	8.30	173.02	164.72	6.9		800	6.6	853	104.0	16.0	38.0	5.1	43.00	289.0	133.0	3.3	0.4	442	
783	WW16	C	259.4	1786.2	89/05/07	9.03	173.02	163.99	7.2		1200	6.6	970	107.0	25.0	46.0	5.4	48.00	240.0	191.0	1.5	0.2	494	
784	WW16	C	259.4	1786.2	89/06/08	9.03	173.02	163.99	6.3		1200	6.4	1280	121.0	24.0	64.0	9.7	56.00	181.0	297.0	0.0	0.3	605	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		°C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
785	WW16	C	259.4	1786.2	89/07/04	8.89	173.02	164.13	6.4	28.2	1500	6.2	1190	129.0	19.0	51.0	8.6	55.00	175.0	284.0	0.6	1.2	579	
786	WW16	C	259.4	1786.2	89/08/07	9.47	173.02	163.55	6.6	33.7	2200	6.3	1730	137.0	42.0	94.0	15.0	61.00	117.0	474.0	0.6	0.6	820	
787	WW16	C	259.4	1786.2	89/09/08	8.90	173.02	164.12	7.0	27.9	1800	6.6	1600	128.0	31.0	107.0	15.0	46.00	101.0	442.0	0.8	0.3	773	
788	WW16	C	259.4	1786.2	89/10/17	8.87	173.02	164.15	7.4		1900	6.0	1730	155.0	11.0	122.0	16.0	47.00	60.0	465.0	0.9	0.0	800	
789	WW16	C	259.4	1786.2	89/11/02	9.00	173.02	164.02	6.4		1800	5.9	1740	110.0	38.0	101.0	12.0	55.00	51.0	409.0	0.0	0.0	695	704
790	WW16	C	259.4	1786.2	89/12/00		173.02																	
791	WW16	C	259.4	1786.2	90/01/14	9.13	173.02	163.89	7.1		1600	7.2	1560	56.0	61.0	116.0	8.3	46.00	60.0	439.0	2.2	0.4	712	
792	WW16	C	259.4	1786.2	90/02/13	9.23	173.02	163.79	6.9		1400	6.7	1510	100.0	31.0	121.0	8.8	46.00	72.0	416.0	0.0	0.0	711	
793	WW16	C	259.4	1786.2	90/03/12	9.32	164.15	154.83	6.9		1300	6.0	1510	95.0	29.0	109.0	9.1	37.00	53.0	394.0	1.1	0.0	663	690
794	WW16	C	259.4	1786.2	90/04/08	9.05	164.15	155.10	7.1		1100	7.5	1300	97.0	24.0	91.0	10.0	59.00	69.0	347.0	1.2	0.0	604	
795	WW17	C	262.6	1787.2	89/09/15	7.65	196.08	188.43	6.8		900	6.9	772	89.0	21.0	38.0	8.9	0.25	445.0	51.0	1.9	0.9	429	
796	WW17	C	262.6	1787.2	89/10/16	7.91	196.08	188.17	7.7		900	7.9	741	92.0	16.0	37.0	11.0	0.47	412.0	35.0	0.5	0.0	395	
797	WW17	C	262.6	1787.2	89/11/02	8.19	196.08	187.89	6.9		800													
798	WW17	C	262.6	1787.2	89/12/00		196.08																	
799	WW17	C	262.6	1787.2	90/01/13	8.33	196.08	187.75	7.1		700	8.1	741	83.0	21.0	33.0	6.0	0.36	412.0	36.0	0.0	0.0	383	434
800	WW17	C	262.6	1787.2	90/02/14	8.50	196.08	187.58	6.7		600	7.0	765	88.0	24.0	33.0	8.9	2.00	440.0	37.0	1.7	0.1	409	416
801	WW17	C	262.6	1787.2	90/03/12	8.56	196.08	187.52	7.1		700	7.2	811	90.0	26.0	31.0	6.5	0.00	437.0	30.0	0.6	9.1	408	458
802	WW17	C	262.6	1787.2	90/04/08	8.29	196.08	187.79	7.3		600	8.4	357	16.0	17.0	29.0	5.6	0.00	114.0	22.0	1.5	2.3	173	
803	WW18	C	269.4	1787.8	89/10/16	32.92	216.21	189.00	7.8		700	7.5	695	107.0	12.0	25.0	6.8	0.46	431.0	10.0	5.7	0.3	378	
804	WW18	C	269.4	1787.8	89/11/16	33.30	216.21	188.00	7.8		800	8.1	631	98.0	16.0	25.0	5.6	0.50	437.0	12.0	2.6	0.0	374	527
805	WW18	C	269.4	1787.8	89/12/00		216.21	188.50																
806	WW18	C	269.4	1787.8	90/01/13	33.13	216.21	189.00	7.1		700	7.9	709	91.0	19.0	27.0	4.2	1.10	423.0	12.0	3.1	0.0	364	408
807	WW18	C	269.4	1787.8	90/02/14	33.11	216.21	187.80	7.1		600	7.3	696	98.0	16.0	25.0	4.1	0.95	442.0	12.0	2.2	0.4	375	
808	WW18	C	269.4	1787.8	90/03/12	33.10	216.21	190.00	7.1		600	7.5	717	109.0	15.0	25.0	4.3	0.00	433.0	11.0	4.2	0.4	373	258
809	WW18	C	269.4	1787.8	90/04/08	32.14	216.21	191.00	6.9		300	7.0	670	101.0	14.0	24.0	4.6	0.00	376.0	12.0	2.2	1.3	344	
810	WW3	C	269.1	1808.7	89/03/13	1.57	153.65	152.08	7.0		1100	7.1	1010	106.0	13.0	87.0	5.1	1.80	370.0	169.0	2.5	0.3	566	
811	WW3	C	269.1	1808.7	89/04/09	1.95	153.65	151.70	6.8		900	7.8	1120	110.0	15.0	94.0	4.1	1.10	377.0	164.0	2.1	0.1	575	
812	WW3	C	269.1	1808.7	89/05/11	2.10	153.65	151.55	7.0		1010	7.0	1030	111.0	9.2	98.0	3.6	0.98	369.0	164.0	1.1	0.0	569	
813	WW3	C	269.1	1808.7	89/06/09	1.91	153.65	151.74	6.8		1000	7.0	1060	114.0	6.3	90.0	3.7	1.80	317.0	160.0	1.5	0.0	559	
814	WW3	C	269.1	1808.7	89/07/13	1.98	153.65	151.67	6.7	30.7	1400	7.2	1050	109.0	16.0	93.0	3.7	6.10	385.0	158.0	0.0	1.2	571	
815	WW3	C	269.1	1808.7	89/08/10	1.70	153.65	151.95	8.6	24.9	1100	6.9	1020	113.0	6.5	88.0	4.3	5.20	373.0	160.0	1.9	0.6	558	
816	WW3	C	269.1	1808.7	89/09/16		153.65		7.4		1100	7.0	1090	112.0	10.0	92.0	4.1	3.20	342.0	158.0	2.8	0.4	548	
817	WW3	C	269.1	1808.7	89/10/20	1.42	153.65	152.23	7.0		1200	8.4	1030	105.0	15.0	92.0	3.0	4.00	303.0	160.0	1.8	0.0	541	
818	WW3	C	269.1	1808.7	89/11/18	1.36	153.65	152.29	7.6		1200	7.9	1050	112.0	13.0	90.0	3.2	3.50	366.0	165.0	1.8	0.0	564	746
819	WW3	C	269.1	1808.7	89/12/00		153.65																	
820	WW3	C	269.1	1808.7	90/01/18	2.29	153.65	151.36	6.8		1000	7.8	821	49.0	9.2	86.0	2.1	3.40	168.0	161.0	0.6	0.0	392	
821	WW3	C	269.1	1808.7	90/02/17	2.54	153.65	151.11	6.9		1000	7.6	1100	108.0	16.0	75.0	2.3	2.80	362.0	177.0	0.0	0.0	556	
822	WW3	C	269.1	1808.7	90/03/15	2.60	153.65	151.05	6.7		1200	7.3	994	86.0	8.8	94.0	2.4	0.00	309.0	160.0	0.7	0.0	504	
823	WW3	C	269.1	1808.4	90/04/11	2.39	153.65	151.26	7.3		900	7.6	973	82.0	11.0	94.0	3.0	0.00	292.0	165.0	0.0	0.0	498	
824	WW4	C	269.4	1809.3	89/03/00		152.19																	
825	WW4	C	269.4	1809.3	89/04/09	0.15	152.19	152.04	6.7		900	7.4	1060	100.0	11.0	101.0	3.8	3.80	357.0	159.0	6.6	0.2	558	
826	WW4	C	269.4	1809.3	89/05/11		152.19																	
827	WW4	C	269.4	1809.3	89/06/09	0.07	152.19	152.12	6.9		1000	7.1	1040	102.0	5.6	98.0	3.7	9.10	349.0	160.0	0.7	0.3	543	
828	WW4	C	269.4	1809.3	89/07/13	0.05	152.19	152.14	7.5	30.3	1200	7.0	1040	83.0	22.0	102.0	4.0	5.30	357.0	163.0	4.3	0.7	555	
829	WW4	C	269.4	1809.3	89/08/10		152.19		8.7	27.3	1100	7.1	1070	108.0	9.5	95.0	4.0	0.56	354.0	171.0	3.4	3.6	569	
830	WW4	C	269.4	1809.3	89/09/16		152.19		7.5		1200	7.1	1080	106.0	9.4	95.0	3.7	1.30	329.0	166.0	2.9	0.0	545	
831	WW4	C	269.4	1809.3	89/10/20		152.19		7.0		1100	8.0	1010	102.0	13.0	97.0	3.0	0.38	335.0	166.0	1.9	0.0	557	
832	WW4	C	269.4	1809.3	89/11/18		152.19		7.8		1100	7.4	1050	106.0	19.0	96.0	3.7	0.66	355.0	167.0	2.3	0.0	569	636
833	WW4	C	269.4	1809.3	89/12/00		152.19																	
834	WW4	C	269.4	1809.3	90/01/18	0.36	152.19	151.83	6.9		1000	7.2	1050	106.0	19.0	96.0	3.7	0.66	355.0	167.0	2.3	0.0	569	636
835	WW4	C	269.4	1809.3	90/02/17	0.56	152.19	151.63	7.0		1000	7.5	1070	105.0	11.0	91.0	2.2	3.60	354.0	164.0	0.0	0.2	549	672
836	WW4	C	269.4	1809.3	90/03/15	0.72	152.19	151.47	7.0		1000	7.2	898	71.0	8.4	94.0	2.3	0.00	251.0	158.0	0.0	0.0	457	
837	WW4	C	269.4	1809.3	90/04/11	0.45	152.19	151.74	7.4		900	7.4	1060	105.0	11.0	90.0	2.7	0.11	358.0	157.0	0.0	0.0	542	
838	WW8	C	266.5	1787.3	89/03/19	0.40	180.81	180.41	8.5		700	7.0	678	88.0	16.0	33.0	5.2	0.18	442.0	15.0	0.0	0.0	375	
839	WW8	C	266.5	1787.3	89/04/07	0.43	180.81	180.38	6.6		700	7.2	681	86.0	21.0	33.0	5.0	0.44	452.0	17.0	0.9	0.3	385	
840	WW8	C	266.5	1787.3	89/05/09	0.03	180.81	180.78	7.5		700	7.3	666	86.0	21.0	34.0	3.9	0.25	454.0	16.0	0.5	0.0	385	

Table 1.3.3 Montly monitoring water levels and chemical compositions of groundwater and surface water in Hin Tank Hydrogeologic Province (Sub-Basin C) (Cont)

No.	WELL NO.	SUB-BASIN	LOCAX	LOCAY	DATE	SWL	ELA	HEAD	FpH	FTEMP	FEc	LpH	LEc	Ca	Mg	Na	K	Fe	HCO3	Cl	SO4	NO3	TDS	TDSEVP
						m	m	m		° C	µS		µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
841	WW8	C	266.5	1787.3	89/06/08	0.26	180.81	180.55	6.9		600	7.2	695	91.0	17.0	31.0	4.7	0.26	446.0	15.0	0.3	0.1	379	
842	WW8	C	266.5	1787.3	89/07/04	0.30	180.81	180.51																
843	WW8	C	266.5	1787.3	89/08/07	0.78	180.81	180.03	6.6	32.3	800	7.3	710	88.0	19.0	32.0	5.5	0.72	446.0	17.0	0.5	0.0	382	
844	WW8	C	266.5	1787.3	89/09/15		180.81		6.9		700	6.9	656	88.0	18.0	29.0	5.5	0.27	446.0	16.0	0.0	0.6	372	
845	WW8	C	266.5	1787.3	89/10/16	0.56	180.81	180.25	8.0		800	7.4	700	88.0	18.0	35.0	5.8	0.25	436.0	1.0	0.0	0.0	377	
846	WW8	C	266.5	1787.3	89/11/02	0.86	180.81	179.95	7.3		700	7.3	677	87.0	24.0	32.0	5.0	0.15	416.0	18.0	0.0	0.0	371	576
847	WW8	C	266.5	1787.3	89/12/00		180.81																	
848	WW8	C	266.5	1787.3	90/01/13	3.54	180.81	177.27	7.1		600	7.2	720	84.0	19.0	35.0	3.3	0.00	439.0	16.0	0.0	0.0	373	374
849	WW8	C	266.5	1787.3	90/02/14	1.80	180.81	179.01	6.8		400	7.0	660	84.0	18.0	30.0	5.1	0.05	421.0	16.0	0.6	0.0	362	334
850	WW8	C	266.5	1787.3	90/03/12	1.03	180.81	179.78	7.0		600	7.5	738	87.0	19.0	34.0	3.9	0.00	429.0	17.0	0.9	0.5	372	
851	WW8	C	266.5	1787.3	90/04/08	0.73	180.81	180.08	6.6		500	7.3	686	87.0	20.0	37.0	42.0	0.00	450.0	15.0	1.7	44.0	430	
852	WW9	C	282.6	1775.6	89/03/17	8.90	180.00	171.10	7.8		700	6.9	665	103.0	21.0	11.0	5.1	0.43	452.0	7.9	0.5	0.0	371	
853	WW9	C	282.6	1775.6	89/04/06	8.58	180.00	171.42	6.6		600	6.6	598	80.0	15.0	21.0	5.4	0.20	367.0	15.0	0.0	0.0	318	
854	WW9	C	282.6	1775.6	89/05/06	9.50	180.00	170.50	7.0		600	6.7	596	87.0	12.0	23.0	5.1	5.80	396.0	14.0	0.0	0.0	336	
855	WW9	C	282.6	1775.6	89/06/04	8.83	180.00	171.17	6.6		600	7.0	603	90.0	9.1	17.0	5.8	23.00	377.0	13.0	0.0	0.9	321	
856	WW9	C	282.6	1775.6	89/07/09	7.61	180.00	172.39	6.6	27.9	700	6.7	610	92.0	14.0	18.0	6.2	1.80	392.0	16.0	0.0	0.9	340	
857	WW9	C	282.6	1775.6	89/08/06	7.63	180.00	172.37	6.6	31.2	800	6.7	649	92.0	14.0	18.0	5.6	20.00	389.0	17.0	0.0	0.0	339	
858	WW9	C	282.6	1775.6	89/09/07	6.72	180.00	173.28	7.2	26.8	700	6.5	982	102.0	14.0	19.0	7.6	1.20	410.0	25.0	3.9	3.5	376	
859	WW9	C	282.6	1775.6	89/10 13	7.14	180.00	172.86	7 4		600	7.1	623	88.0	14.0	8.0	6.4	2.4	376.0	21.0	0.0	0.5	334	
860	W 9	C	282.6	1775.6	89/11/04	7.52	180.00	172.48	7.3		700	7.0	600	90.0	17.0	17.0	5.3	7.90	386.0	16.0	0.0	0.0	335	
861	WW9	C	282.6	1775.6	89/12/17	8.70	180.00	171.30	7.6		600	7.4	627	88.0	16.0	20.0	5.9	0.91	392.0	14.0	0.4	0.3	337	
862	WW9	C	282.6	1775.6	90/01/13	9.12	180.00	170.88	6.9		500	6.6	662	87.0	18.0	19.0	2.3	2.00	397.0	13.0	0.0	0.6	336	
863	WW9	C	282.6	1775.6	90/02/13	9.90	180.00	170.10	6.6		500	6.7	630	93.0	15.0	19.0	5.9	1.00	398.0	13.0	0.6	0.2	342	
864	WW9	C	282.6	1775.6	90/03/11	10.04	180.00	169.96	7.0		600	7.0	682	88.0	18.0	22.0	3.9	0.00	391.0	16.0	0.3	0.3	341	
865	WW9	C	282.6	1775.6	90/04/07	9.49	180.00	170.51	6.5		600	7.6	622	89.0	17.0	21.0	4.3	0.11	355.0	14.0	0.0	0.5	320	

Appendix 3.1 Water -level measurements in observation wells
during pumping well no. WW4

SINGLE RATE TEST

Pumping well: WW4
Observation well: P1 to P8
Depth of well:
Screen or Slot:
Reference Level: 1.95 m. above the ground surface
Location:
Static or initial water level:
Discharge Rate: 3857.24 cubic meter/day or 707.70 U.S gpm.
Date: 20/7/89

D = drawdown measurement
R= recovery measurement

Pump Test at Ban Nong Khai Nun

Obs well	Pumping well	TIME(min)	SWL(m) bgs	DDRC(m)	TYPE
P1	WW4	0.00	1.39	0.00	D
P1	WW4	12.00	1.60	0.22	D
P1	WW4	34.00	1.71	0.32	D
P1	WW4	57.00	1.77	0.38	D
P1	WW4	84.00	1.82	0.44	D
P1	WW4	226.00	2.20	0.82	D
P1	WW4	365.00	2.19	0.81	D
P1	WW4	487.00	2.29	0.91	D
P1	WW4	668.00	2.40	1.02	D
P1	WW4	832.00	2.58	1.20	D
P1	WW4	953.00	2.73	1.35	D
P1	WW4	1076.00	2.76	1.37	D
P1	WW4	1188.00	2.90	1.52	D
P1	WW4	1303.00	2.91	1.53	D
P1	WW4	1428.00	2.98	1.59	D
P1	WW4	1523.00	3.11	1.72	D
P1	WW4	1733.00	3.27	1.89	D
P1	WW4	1912.00	3.28	1.89	D
P1	WW4	2111.00	3.31	1.93	D
P1	WW4	2281.00	3.39	2.00	D
P1	WW4	2460.00	3.48	2.09	D
P1	WW4	2653.00	3.52	2.13	D
P1	WW4	2822.00	3.58	2.20	D
P1	WW4	2988.00	3.66	2.28	D
P1	WW4	3215.00	3.73	2.34	D
P1	WW4	3367.00	3.75	2.37	D
P1	WW4	3650.00	3.73	2.34	D
P1	WW4	3739.00	3.77	2.38	D
P1	WW4	3899.00	3.90	2.51	D
P1	WW4	4082.00	3.94	2.55	D
P1	WW4	4246.00	3.98	2.59	D
P1	WW4	4443.00	4.00	2.62	D
P1	WW4	4689.00	4.04	2.66	D
P1	WW4	4803.00	4.00	2.62	D
P1	WW4	4999.00	3.93	2.54	D
P1	WW4	5155.00	3.97	2.58	D
P1	WW4	5346.00	4.07	2.69	D
P1	WW4	0.00	4.31	0.00	R
P1	WW4	5.00	4.22	0.09	R
P1	WW4	10.00	4.12	0.19	R
P1	WW4	15.00	4.07	0.24	R
P1	WW4	20.00	4.04	0.27	R
P1	WW4	25.00	4.02	0.29	R
P1	WW4	30.00	4.00	0.31	R
P1	WW4	35.00	3.98	0.33	R
P1	WW4	40.00	3.97	0.34	R
P1	WW4	45.00	3.93	0.38	R
P1	WW4	50.00	3.93	0.38	R
P1	WW4	60.00	3.93	0.38	R
P1	WW4	80.00	3.92	0.39	R
P1	WW4	90.00	3.88	0.43	R
P1	WW4	100.00	3.85	0.46	R
P1	WW4	120.00	3.82	0.49	R
P1	WW4	135.00	3.81	0.50	R
P1	WW4	155.00	3.79	0.52	R
P1	WW4	1450.00	2.34	1.97	R
P1	WW4	2930.00	1.80	2.51	R
P2	WW4	0.00	0.26	0.00	D
P2	WW4	9.00	0.49	0.23	D
P2	WW4	36.00	0.66	0.40	D
P2	WW4	60.00	0.71	0.45	D
P2	WW4	71.00	0.00		D
P2	WW4	229.00	0.98	0.72	D
P2	WW4	369.00	1.14	0.88	D
P2	WW4	490.00	1.24	0.98	D
P2	WW4	670.00	1.35	1.10	D
P2	WW4	817.00	1.48	1.23	D
P2	WW4	958.00	1.69	1.43	D
P2	WW4	1088.00	1.78	1.53	D
P2	WW4	1191.00	1.83	1.58	D
P2	WW4	1311.00	1.86	1.61	D
P2	WW4	1431.00	1.92	1.67	D
P2	WW4	1526.00	2.01	1.75	D
P2	WW4	1737.00	2.21	1.96	D

Appendix 3.1 Water -level measurements in observation wells (Cont.)

during pumping well no. WW4

Obs. well	Pumping well	TIME(min)	SWL(m) bgs	DDRC(m)	TYPE
P2	WW4	1914.00	2.23	1.98	D
P2	WW4	2092.00	2.25	2.00	D
P2	WW4	2289.00	2.35	2.10	D
P2	WW4	2465.00	2.42	2.17	D
P2	WW4	2636.00	2.47	2.22	D
P2	WW4	2806.00	2.53	2.27	D
P2	WW4	2982.00	2.54	2.29	D
P2	WW4	3207.00	2.69	2.44	D
P2	WW4	3360.00	2.71	2.45	D
P2	WW4	3563.00	2.68	2.43	D
P2	WW4	3733.00	2.72	2.47	D
P2	WW4	3895.00	2.86	2.60	D
P2	WW4	4073.00	2.89	2.64	D
P2	WW4	4242.00	2.89	2.64	D
P2	WW4	4438.00	2.94	2.69	D
P2	WW4	4682.00	2.96	2.71	D
P2	WW4	4796.00	2.91	2.66	D
P2	WW4	4995.00	2.91	2.66	D
P2	WW4	5149.00	2.94	2.69	D
P2	WW4	5340.00	3.00	2.75	D
P2	WW4	0.00	3.54	0.00	R
P2	WW4	5.00	3.29	0.25	R
P2	WW4	10.00	3.25	0.29	R
P2	WW4	15.00	3.19	0.35	R
P2	WW4	20.00	3.17	0.37	R
P2	WW4	25.00	3.14	0.40	R
P2	WW4	30.00	3.11	0.43	R
P2	WW4	35.00	3.10	0.44	R
P2	WW4	40.00	3.08	0.46	R
P2	WW4	45.00	3.07	0.47	R
P2	WW4	50.00	3.06	0.48	R
P2	WW4	60.00	3.06	0.48	R
P2	WW4	70.00	0.04	3.50	R
P2	WW4	80.00	3.03	0.51	R
P2	WW4	90.00	0.01	3.53	R
P2	WW4	100.00	2.99	0.55	R
P2	WW4	120.00	2.97	0.57	R
P2	WW4	140.00	2.96	0.58	R
P2	WW4	1455.00	1.19	2.35	R
P2	WW4	2918.00	0.66	2.88	R
P3	WW4	0.00	0.48	0.00	D
P3	WW4	10.00	0.50	0.02	D
P3	WW4	20.00	0.71	0.22	D
P3	WW4	35.00	0.67	0.19	D
P3	WW4	45.00	0.69	0.21	D
P3	WW4	65.00	0.72	0.24	D
P3	WW4	110.00	0.81	0.33	D
P3	WW4	230.00	0.97	0.48	D
P3	WW4	340.00	1.17	0.68	D
P3	WW4	460.00	1.16	0.68	D
P3	WW4	820.00	1.35	0.86	D
P3	WW4	940.00	1.48	1.00	D
P3	WW4	1050.00	1.58	1.10	D
P3	WW4	1170.00	1.64	1.15	D
P3	WW4	1298.00	1.67	1.19	D
P3	WW4	1417.00	1.69	1.21	D
P3	WW4	1650.00	1.87	1.39	D
P3	WW4	1890.00	1.97	1.49	D
P3	WW4	2140.00	2.09	1.61	D
P3	WW4	2375.00	2.10	1.62	D
P3	WW4	2615.00	2.18	1.70	D
P3	WW4	2861.00	2.25	1.76	D
P3	WW4	3095.00	2.34	1.85	D
P3	WW4	3382.00	2.38	1.90	D
P3	WW4	3580.00	2.38	1.90	D
P3	WW4	3817.00	2.45	1.97	D
P3	WW4	4057.00	2.54	2.06	D
P3	WW4	4295.00	2.56	2.08	D
P3	WW4	4557.00	2.62	2.14	D
P3	WW4	4780.00	2.65	2.17	D
P3	WW4	5027.00	2.60	2.12	D
P3	WW4	5257.00	2.64	2.16	D
P3	WW4	5420.00	2.68	2.20	D
P3	WW4	5625.00	2.65	2.17	D
P3	WW4	0.00	2.65	0.00	R
P3	WW4	7.00	2.63	0.02	R
P3	WW4	15.00	2.59	0.06	R
P3	WW4	27.00	2.54	0.11	R
P3	WW4	33.00	2.49	0.16	R
P3	WW4	44.00	2.45	0.20	R
P3	WW4	60.00	2.39	0.26	R
P3	WW4	74.00	2.36	0.29	R
P3	WW4	95.00	2.32	0.33	R
P3	WW4	10.00	2.29	0.36	R
P3	WW4	132.00	2.27	0.38	R

Appendix 3.1 Water -level measurements in observation wells (Cont.)
during pumping well no. WW4

Obs. well	Pumping well	TIME(min)	SWL(m) bgs	DDRC(m)	TYPE
P3	WW4	142.00	2.26	0.39	R
P3	WW4	180.00	2.22	0.43	R
P3	WW4	1410.00	1.38	1.27	R
P3	WW4	2883.00	0.98	1.67	R
P4	WW4	0	0.297	0.000	D
P4	WW4	15	0.294	-0.003	D
P4	WW4	55	0.285	-0.012	D
P4	WW4	70	0.280	-0.017	D
P4	WW4	105	0.275	-0.022	D
P4	WW4	210	0.277	-0.020	D
P4	WW4	330	0.284	-0.013	D
P4	WW4	450	0.295	-0.002	D
P4	WW4	810	0.320	0.023	D
P4	WW4	930	0.342	0.045	D
P4	WW4	1060	0.372	0.075	D
P4	WW4	1170	0.403	0.106	D
P4	WW4	1290	0.420	0.123	D
P4	WW4	1410	0.435	0.138	D
P4	WW4	1660	0.499	0.202	D
P4	WW4	1890	0.545	0.248	D
P4	WW4	2130	0.604	0.307	D
P4	WW4	2370	0.643	0.346	D
P4	WW4	2610	0.693	0.396	D
P4	WW4	2850	0.745	0.448	D
P4	WW4	3090	0.780	0.483	D
P4	WW4	3370	0.840	0.543	D
P4	WW4	3610	0.880	0.583	D
P4	WW4	3850	0.903	0.606	D
P4	WW4	4090	0.942	0.645	D
P4	WW4	4330	0.980	0.683	D
P4	WW4	4587	1.200	0.903	D
P4	WW4	4690	1.040	0.743	D
P4	WW4	4930	0.990	0.693	D
P4	WW4	5170	1.115	0.818	D
P4	WW4	5275	1.135	0.838	D
P4	WW4	5480	1.167	0.870	D
P5	WW4	0.00	1.37	0.00	D
P5	WW4	100.00	1.47	0.10	D
P5	WW4	281.00	1.49	0.12	D
P5	WW4	433.00	1.50	0.13	D
P5	WW4	659.00	1.49	0.12	D
P5	WW4	813.00	1.48	0.11	D
P5	WW4	915.00	1.48	0.11	D
P5	WW4	1025.00	1.49	0.12	D
P5	WW4	1146.00	1.49	0.12	D
P5	WW4	1323.00	1.50	0.13	D
P5	WW4	1494.00	1.49	0.12	D
P5	WW4	1679.00	1.49	0.12	D
P5	WW4	1874.00	1.50	0.13	D
P5	WW4	2196.00	1.50	0.13	D
P5	WW4	2401.00	1.50	0.13	D
P5	WW4	2580.00	1.52	0.15	D
P5	WW4	2762.00	1.52	0.15	D
P5	WW4	2943.00	1.52	0.15	D
P5	WW4	3168.00	1.52	0.15	D
P5	WW4	3544.00	1.56	0.19	D
P5	WW4	3782.00	1.56	0.19	D
P5	WW4	4009.00	1.57	0.20	D
P5	WW4	4262.00	1.59	0.22	D
P5	WW4	4676.00	1.60	0.23	D
P5	WW4	4828.00	1.59	0.22	D
P5	WW4	5155.00	1.62	0.25	D
P5	WW4	5425.00	1.62	0.25	D
P5	WW4	5587.00	1.64	0.27	D
P5	WW4	5596.00	1.64	0.27	D
P5	WW4	0.00	1.64	0.00	D
P5	WW4	1.00	1.64	0.00	D
P5	WW4	2.00	1.64	0.00	D
P5	WW4	3.00	1.64	0.00	D
P5	WW4	4.00	1.64	0.00	D
P5	WW4	5.00	1.64	0.00	D
P5	WW4	6.00	1.64	0.00	D
P5	WW4	7.00	1.64	0.00	D
P5	WW4	8.00	1.64	0.00	D
P5	WW4	10.00	1.64	0.00	D
P5	WW4	12.00	1.64	0.00	D
P5	WW4	14.00	1.64	0.00	D
P5	WW4	16.00	1.64	0.00	D
P5	WW4	18.00	1.64	0.00	D
P5	WW4	20.00	1.64	0.00	D
P5	WW4	25.00	1.64	0.00	D
P5	WW4	30.00	1.64	0.00	D
P5	WW4	67.00	1.64	0.00	D
P5	WW4	80.00	1.64	0.00	D
P5	WW4	150.00	1.64	0.00	D

Appendix 3.1 Water -level measurements in observation wells (Cont.)

during pumping well no. WW4

Obs. well	Pumping well	TIME(min)	SWL(m) bgs	DDRC(m)	TYPE
P5	WW4	1460.00	1.30	0.33	D
P5	WW4	2901.00	1.27	0.37	D
P6	WW4	0.00	0.94	0.00	D
P6	WW4	21.00	0.94	0.00	D
P6	WW4	43.00	0.93	-0.01	D
P6	WW4	111.00	0.94	0.00	D
P6	WW4	209.00	0.95	0.01	D
P6	WW4	338.00	0.98	0.04	D
P6	WW4	459.00	0.99	0.06	D
P6	WW4	639.00	0.99	0.05	D
P6	WW4	838.00	0.99	0.06	D
P6	WW4	937.00	1.01	0.07	D
P6	WW4	1067.00	1.21	0.27	D
P6	WW4	1175.00	1.11	0.17	D
P6	WW4	1294.00	1.10	0.17	D
P6	WW4	1415.00	1.10	0.16	D
P6	WW4	1541.00	1.20	0.26	D
P6	WW4	1714.00	1.05	0.11	D
P6	WW4	1896.00	1.07	0.13	D
P6	WW4	2076.00	1.06	0.12	D
P6	WW4	2261.00	1.08	0.14	D
P6	WW4	2446.00	1.09	0.16	D
P6	WW4	2610.00	1.10	0.16	D
P6	WW4	2793.00	1.10	0.16	D
P6	WW4	2971.00	1.10	0.17	D
P6	WW4	3192.00	1.14	0.20	D
P6	WW4	3356.00	1.17	0.23	D
P6	WW4	3583.00	1.70	0.76	D
P6	WW4	3711.00	1.18	0.24	D
P6	WW4	3881.00	1.18	0.24	D
P6	WW4	4066.00	1.18	0.24	D
P6	WW4	4232.00	1.20	0.26	D
P6	WW4	4430.00	1.24	0.30	D
P6	WW4	4620.00	1.28	0.34	D
P6	WW4	4791.00	1.27	0.33	D
P6	WW4	4984.00	1.29	0.35	D
P6	WW4	5142.00	1.30	0.36	D
P6	WW4	5328.00	1.32	0.38	D
P6	WW4	0.00	1.34	0.00	R
P6	WW4	10.00	1.35	-0.01	R
P6	WW4	26.00	1.34	0.00	R
P6	WW4	33.00	1.34	0.00	R
P6	WW4	41.00	1.35	-0.01	R
P6	WW4	52.00	1.35	-0.01	R
P6	WW4	60.00	1.36	-0.02	R
P6	WW4	70.00	1.33	0.01	R
P6	WW4	83.00	1.35	-0.01	R
P6	WW4	94.00	1.33	0.01	R
P6	WW4	125.00	1.35	-0.01	R
P6	WW4	156.00	1.35	-0.01	R
P6	WW4	1395.00	1.34	0.00	R
P6	WW4	2868.00	1.33	0.01	R
P7	WW4	0.00	2.79	0.00	D
P7	WW4	26.00	2.81	0.02	D
P7	WW4	41.00	2.84	0.04	D
P7	WW4	118.00	2.90	0.10	D
P7	WW4	214.00	2.96	0.17	D
P7	WW4	351.00	3.05	0.25	D
P7	WW4	474.00	3.10	0.31	D
P7	WW4	653.00	3.12	0.33	D
P7	WW4	846.00	3.26	0.46	D
P7	WW4	945.00	3.32	0.52	D
P7	WW4	1072.00	3.40	0.60	D
P7	WW4	1179.00	3.42	0.63	D
P7	WW4	1299.00	3.46	0.66	D
P7	WW4	1421.00	3.48	0.69	D
P7	WW4	1547.00	3.55	0.75	D
P7	WW4	1721.00	3.63	0.83	D
P7	WW4	1902.00	3.70	0.91	D
P7	WW4	2081.00	3.71	0.92	D
P7	WW4	2267.00	3.78	0.98	D
P7	WW4	2455.00	3.94	1.14	D
P7	WW4	2633.00	3.93	1.14	D
P7	WW4	2802.00	3.99	1.20	D
P7	WW4	2977.00	4.00	1.21	D
P7	WW4	3199.00	4.07	1.28	D
P7	WW4	3375.00	4.11	1.32	D
P7	WW4	3579.00	4.13	1.33	D
P7	WW4	3722.00	4.14	1.34	D
P7	WW4	3889.00	4.19	1.40	D
P7	WW4	4094.00	4.24	1.45	D
P7	WW4	4238.00	4.26	1.46	D
P7	WW4	4435.00	4.30	1.50	D
P7	WW4	4677.00	4.32	1.53	D
P7	WW4	4810.00	4.35	1.55	D

Appendix 3.1 Water -level measurements in observation wells (Cont.)

during pumping well no. WW4

Obs. well	Pumping well	TIME(min)	SWL(m) bgs	DDRC(m)	TYPE
P7	WW4	4990.00	4.36	1.57	D
P7	WW4	5147.00	4.38	1.58	D
P7	WW4	5337.00	4.45	1.66	D
P7	WW4	0.00	4.44	0.00	R
P7	WW4	4.00	4.45	-0.01	R
P7	WW4	19.00	4.40	0.04	R
P7	WW4	30.00	4.33	0.11	R
P7	WW4	48.00	4.32	0.12	R
P7	WW4	49.00	4.40	0.04	R
P7	WW4	56.00	4.40	0.04	R
P7	WW4	65.00	4.32	0.12	R
P7	WW4	79.00	4.34	0.10	R
P7	WW4	87.00	4.33	0.11	R
P7	WW4	111.00	4.37	0.07	R
P7	WW4	132.00	4.33	0.11	R
P7	WW4	1389.00	3.86	0.58	R
P7	WW4	2859.00	3.50	0.94	R
P8	WW4	0.00	2.73	0.00	D
P8	WW4	28.00	2.73	0.00	D
P8	WW4	50.00	2.74	0.00	D
P8	WW4	117.00	2.74	0.00	D
P8	WW4	216.00	2.76	0.02	D
P8	WW4	353.00	2.81	0.08	D
P8	WW4	473.00	2.88	0.14	D
P8	WW4	652.00	2.93	0.20	D
P8	WW4	845.00	2.99	0.26	D
P8	WW4	944.00	3.31	0.57	D
P8	WW4	1072.00	3.90	1.17	D
P8	WW4	1181.00	3.14	0.40	D
P8	WW4	1300.00	3.18	0.45	D
P8	WW4	1419.00	3.22	0.49	D
P8	WW4	1550.00	3.25	0.52	D
P8	WW4	1720.00	3.24	0.51	D
P8	WW4	1901.00	3.27	0.54	D
P8	WW4	2081.00	3.44	0.71	D
P8	WW4	2268.00	3.49	0.76	D
P8	WW4	2452.00	3.54	0.80	D
P8	WW4	2632.00	3.58	0.85	D
P8	WW4	2801.00	3.63	0.90	D
P8	WW4	2976.00	3.70	0.97	D
P8	WW4	3198.00	3.77	1.04	D
P8	WW4	3375.00	3.81	1.08	D
P8	WW4	3578.00	3.84	1.10	D
P8	WW4	3721.00	3.84	1.10	D
P8	WW4	3888.00	3.87	1.14	D
P8	WW4	4093.00	3.92	1.19	D
P8	WW4	4236.00	3.92	1.19	D
P8	WW4	4434.00	3.95	1.22	D
P8	WW4	4666.00	3.98	1.25	D
P8	WW4	4810.00	3.98	1.25	D
P8	WW4	4990.00	4.05	1.31	D
P8	WW4	5145.00	4.04	1.31	D
P8	WW4	5336.00	4.09	1.35	D
P8	WW4	0.00	4.13	0.00	R
P8	WW4	4.00	4.12	0.01	R
P8	WW4	18.00	4.08	0.05	R
P8	WW4	29.00	4.13	0.00	R
P8	WW4	34.00	4.09	0.04	R
P8	WW4	45.00	4.04	0.09	R
P8	WW4	56.00	4.11	0.02	R
P8	WW4	63.00	3.91	0.22	R
P8	WW4	78.00	3.90	0.23	R
P8	WW4	90.00	4.10	0.03	R
P8	WW4	112.00	4.11	0.02	R
P8	WW4	131.00	4.10	0.03	R
P8	WW4	1390.00	3.81	0.32	R
P8	WW4	2855.00	3.48	0.65	R
P8	WW4	0.00	2.73	0.00	D
P8	WW4	28.00	2.73	0.00	D
P8	WW4	50.00	2.74	0.00	D
P8	WW4	117.00	2.74	0.00	D
P8	WW4	216.00	2.76	0.02	D
P8	WW4	353.00	2.81	0.08	D
P8	WW4	473.00	2.88	0.14	D
P8	WW4	652.00	2.93	0.20	D
P8	WW4	845.00	2.99	0.26	D
P8	WW4	944.00	3.31	0.57	D
P8	WW4	1072.00	3.90	1.17	D
P8	WW4	1181.00	3.14	0.40	D
P8	WW4	1300.00	3.18	0.45	D
P8	WW4	1419.00	3.22	0.49	D
P8	WW4	1550.00	3.25	0.52	D
P8	WW4	1720.00	3.24	0.51	D
P8	WW4	1901.00	3.27	0.54	D
P8	WW4	2081.00	3.44	0.71	D

Appendix 3.1 Water -level measurements in observation wells (Cont.)

during pumping well no. WW4

Obs. well	Pumping well	TIME(min)	SWL(m) bgs	DDRC(m)	TYPE
P8	WW4	2268.00	3.49	0.76	D
P8	WW4	2452.00	3.54	0.80	D
P8	WW4	2632.00	3.58	0.85	D
P8	WW4	2801.00	3.63	0.90	D
P8	WW4	2976.00	3.70	0.97	D
P8	WW4	3198.00	3.77	1.04	D
P8	WW4	3375.00	3.81	1.08	D
P8	WW4	3578.00	3.84	1.10	D
P8	WW4	3721.00	3.84	1.10	D
P8	WW4	3888.00	3.87	1.14	D
P8	WW4	4093.00	3.92	1.19	D
P8	WW4	4236.00	3.92	1.19	D
P8	WW4	4434.00	3.95	1.22	D
P8	WW4	4666.00	3.98	1.25	D
P8	WW4	4810.00	3.98	1.25	D
P8	WW4	4990.00	4.05	1.31	D
P8	WW4	5145.00	4.04	1.31	D
P8	WW4	5336.00	4.09	1.35	D
P8	WW4	0.00	4.13	0.00	R
P8	WW4	4.00	4.12	0.01	R
P8	WW4	18.00	4.08	0.05	R
P8	WW4	29.00	4.13	0.00	R
P8	WW4	34.00	4.09	0.04	R
P8	WW4	45.00	4.04	0.09	R
P8	WW4	56.00	4.11	0.02	R
P8	WW4	63.00	3.91	0.22	R
P8	WW4	78.00	3.90	0.23	R
P8	WW4	90.00	4.10	0.03	R
P8	WW4	112.00	4.11	0.02	R
P8	WW4	131.00	4.10	0.03	R
P8	WW4	1390.00	3.81	0.32	R
P8	WW4	2855.00	3.48	0.65	R
WW3	WW4	0.00	1.985	0.00	D
WW3	WW4	14.00	2.190	0.21	D
WW3	WW4	33.00	2.287	0.30	D
WW3	WW4	56.00	2.282	0.30	D
WW3	WW4	80.00	2.380	0.40	D
WW3	WW4	222.00	2.608	0.62	D
WW3	WW4	360.00	2.694	0.71	D
WW3	WW4	482.00	2.870	0.89	D
WW3	WW4	661.00	2.995	1.01	D
WW3	WW4	829.00	3.155	1.17	D
WW3	WW4	949.00	3.325	1.34	D
WW3	WW4	1081.00	3.413	1.43	D
WW3	WW4	1185.00	3.475	1.49	D
WW3	WW4	1305.00	3.492	1.51	D
WW3	WW4	1425.00	3.485	1.50	D
WW3	WW4	1518.00	3.660	1.68	D
WW3	WW4	1724.00	3.830	1.85	D
WW3	WW4	1906.00	3.870	1.89	D
WW3	WW4	2085.00	3.880	1.90	D
WW3	WW4	2282.00	3.980	2.00	D
WW3	WW4	2461.00	4.050	2.07	D
WW3	WW4	2655.00	4.110	2.13	D
WW3	WW4	2820.00	4.175	2.19	D
WW3	WW4	2988.00	4.240	2.26	D
WW3	WW4	3218.00	4.320	2.34	D
WW3	WW4	3369.00	4.360	2.38	D
WW3	WW4	3573.00	4.300	2.32	D
WW3	WW4	3740.00	4.340	2.36	D
WW3	WW4	3899.00	4.415	2.43	D
WW3	WW4	4084.00	4.450	2.47	D
WW3	WW4	4247.00	4.530	2.55	D
WW3	WW4	4444.00	4.580	2.60	D
WW3	WW4	4687.00	4.650	2.67	D
WW3	WW4	4805.00	4.560	2.58	D
WW3	WW4	5001.00	4.530	2.55	D
WW3	WW4	5157.00	4.560	2.58	D
WW3	WW4	5349.00	4.620	2.64	D
WW4	WW4	0.00	0.16	0.00	D
WW4	WW4	1.00	2.65	2.49	D
WW4	WW4	1.50	2.68	2.52	D
WW4	WW4	2.00	2.70	2.54	D
WW4	WW4	2.50	2.71	2.55	D
WW4	WW4	3.00	2.72	2.56	D
WW4	WW4	4.00	2.74	2.58	D
WW4	WW4	5.00	2.75	2.59	D
WW4	WW4	6.00	2.76	2.60	D
WW4	WW4	7.00	2.77	2.61	D
WW4	WW4	8.00	2.79	2.63	D
WW4	WW4	9.00	2.80	2.64	D
WW4	WW4	10.00	2.81	2.65	D
WW4	WW4	12.00	2.83	2.67	D
WW4	WW4	14.00	2.85	2.69	D
WW4	WW4	18.00	2.88	2.72	D

Appendix 3.1 Water -level measurements in observation wells (Cont.)

during pumping well no. WW4

Obs. well	Pumping well	TIME(min)	SWL(m) bgs	DDRC(m)	TYPE
WW4	WW4	20.00	2.90	2.74	D
WW4	WW4	30.00	2.92	2.76	D
WW4	WW4	40.00	2.94	2.78	D
WW4	WW4	50.00	2.96	2.80	D
WW4	WW4	60.00	2.98	2.82	D
WW4	WW4	70.00	3.00	2.84	D
WW4	WW4	80.00	3.02	2.86	D
WW4	WW4	90.00	3.06	2.90	D
WW4	WW4	100.00	3.10	2.94	D
WW4	WW4	120.00	3.13	2.97	D
WW4	WW4	140.00	3.16	3.00	D
WW4	WW4	180.00	3.24	3.08	D
WW4	WW4	210.00	3.25	3.09	D
WW4	WW4	330.00	3.40	3.24	D
WW4	WW4	450.00	3.51	3.35	D
WW4	WW4	650.00	3.62	3.46	D
WW4	WW4	810.00	3.73	3.57	D
WW4	WW4	930.00	3.92	3.76	D
WW4	WW4	1050.00	3.96	3.80	D
WW4	WW4	1170.00	4.07	3.91	D
WW4	WW4	1290.00	4.09	3.93	D
WW4	WW4	1410.00	4.11	3.95	D
WW4	WW4	1530.00	4.25	4.09	D
WW4	WW4	1710.00	4.40	4.24	D
WW4	WW4	1890.00	4.43	4.27	D
WW4	WW4	2070.00	4.46	4.30	D
WW4	WW4	2250.00	4.50	4.34	D
WW4	WW4	2430.00	4.57	4.41	D
WW4	WW4	2610.00	4.62	4.46	D
WW4	WW4	2790.00	4.72	4.56	D
WW4	WW4	2970.00	4.79	4.63	D
WW4	WW4	3150.00	4.87	4.71	D
WW4	WW4	3330.00	4.89	4.73	D
WW4	WW4	3510.00	4.89	4.73	D
WW4	WW4	3690.00	4.89	4.73	D
WW4	WW4	3870.00	5.02	4.86	D
WW4	WW4	4051.00	5.02	4.86	D
WW4	WW4	4230.00	5.06	4.90	D
WW4	WW4	4410.00	5.10	4.94	D
WW4	WW4	4590.00	5.12	4.96	D
WW4	WW4	4770.00	5.12	4.96	D
WW4	WW4	4950.00	5.10	4.94	D
WW4	WW4	5130.00	5.10	4.94	D
WW4	WW4	5310.00	5.16	5.00	D
WW4	WW4	5580.00	5.13	4.97	D
WW4	WW4	5615.00	5.12	4.96	D

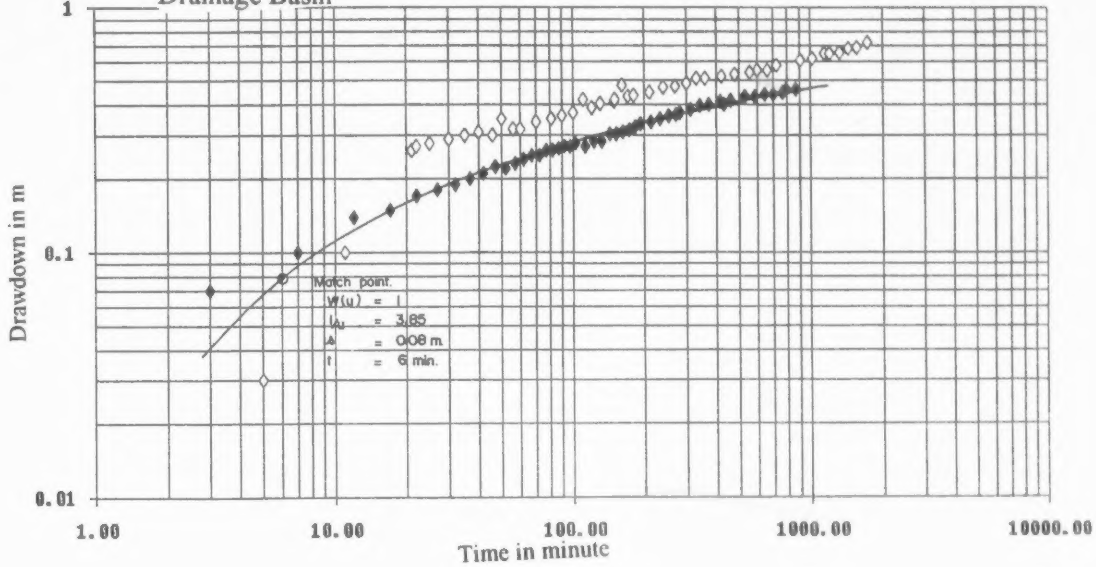
APPENDIX 4.1 THIES FITTING CURVES FOR PARTIALLY PENETRATING WELLS AND ANISOTROPIC AQUIFERS (PART 1)

PUMPING	WELL	OBS	WELL	AQUIFER								MATCH POINT								
WELL#	DEPTH	WELLNO	DEPTH	TYPE	r	l	d	lo	do	b	Kv/Kh	W(u)	1/u	s	t	Q	T	S	H(m)	Qs20
					(m)	(m)	(m)	(m)	(m)	(m)				(m)	(min)	(l/s)	(m2/s)			(l/s)
WW1	46.50			CONC		46.50	28.90			100.00						1.72				
WW2	48.80					40.40	26.70			110.00						1.82				
WW2	48.80	P21	48.00		22.00	40.40	26.70	41.80	39.80	110.00	0.0001	16.00	980.00	0.40	40.00	2.28	5.78E-03	0.0001	10.00	27.5675926
WW3	48.50			UNC		48.50	31.90			152.40						12.95				
WW3	48.50	P1	71.20	UNC	22.00	48.50	31.90	70.50	8.00	152.40	0.0001	3.80	6.15	0.05	8.00	13.76	8.32E-02	0.0537	10.00	396.894792
WW3	48.50	DOH	48.80	UNC	45.00	48.50	31.90	48.80	18.20	152.40						13.76				
WW4	131.10			UNC		131.10	24.38			152.40						44.65				
WW4	131.10	WW3	48.50		300.00	131.10	24.38	48.50	31.90	152.40	0.0010	2.50	21.00	0.40	60.00	44.65	2.22E-02	0.0002	10.00	105.905671
WW4	131.10	P1	66.70	UNC	275.00	131.10	24.38	70.50	8.00	152.40	0.0001	1.60	5.00	0.30	40.00	44.65	1.89E-02	0.0005	10.00	90.3728009
WW4	131.10	P2	30.00	UNC	200.00	131.10	24.38	30.00	8.00	152.40	0.0100	3.80	250.00	0.40	40.00	44.65	3.38E-02	0.0000	10.00	160.97662
WW4	131.10	P3	29.50	UNC	170.00	131.10	24.38	29.50	8.00	152.40	0.0100	7.50	6.35	0.20	50.00	44.65	1.33E-01	0.0087	10.00	635.434144
WW4	131.10	P4	24.60	UNC	325.00	131.10	24.38	24.60	8.00	152.40						44.65				
WW4	131.10	P5	30.90	UNC	530.00	131.10	24.38	30.90	8.00	152.40						44.65				
WW4	131.10	P6	22.00	UNC	265.00	131.10	24.38	22.00	8.00	152.40						44.65				
WW4	131.10	P7	39.00	UNC	560.00	131.10	24.38	39.00	8.00	152.40						44.65				
WW4	131.10	P8	12.50	UNC	570.00	131.10	24.38	12.50	8.00	152.40						44.65				
WW7	120.40					120.40	36.58			400.00						3.28				
WW7	120.40	P19	64.20		19.00	120.40	36.58	59.50	57.50	400.00						3.28				
WW7	120.40	P20	16.70		14.00	120.40	36.58	16.00	15.00	400.00	0.0100	7.00	800.00	0.20	8.00	3.28	9.14E-03	0.0001	10.00	43.5696759
WW11	94.50					94.50	18.28			130.00						0.63				
WW11	94.50	P32	36.50		63.00	94.50	18.28	60.00	52.00	130.00						0.63				
WW11	94.50	NEWZ	18.00		56.00	94.50	18.28	18.00	12.00	130.00						0.63				
WW16	126.50			UNC		126.50	30.50			264.00						41.16				
WW17	149.40			UNC		149.40	24.38	60.00	58.00	188.00						1.14				
WW17	149.40	P79	60.00	UNC	19.00	149.40	24.38			188.00	0.1000	0.89	1.83	0.20	10.00	1.14	4.02E-04		10.00	1.91759259
WW18	152.40					152.40	18.29			212.00						0.85				
P4	24.60			UND		24.60	8.00			152.40						6.31				
PWLR	105.00					104.00	65.00			200.00						0.44				
PWLR	105.00	P74	63.30		48.00	104.00	65.00	44.50	14.50	200.00	0.0010	1.33	2000.00	0.20	300.00	0.44	2.34E-04	0.0000	10.00	1.11435185
PWDF	91.00					82.40	66.00			200.00						3.85				
PWKC	36.00					16.00	4.50			46.00						1.23				
PWTW	94.00					35.70	7.20			72.00						0.44				
PWKS	78.60					46.00	9.00			46.00						1.75				
PWKS	78.60	P11	36.60		4.00	46.00	9.00	13.00	11.00	46.00	0.1000	1.70	4.60	0.20	10.00	1.75	1.19E-03	0.0387	10.00	5.65648148
S913	91.50					85.36	54.88			200.00						11.62				

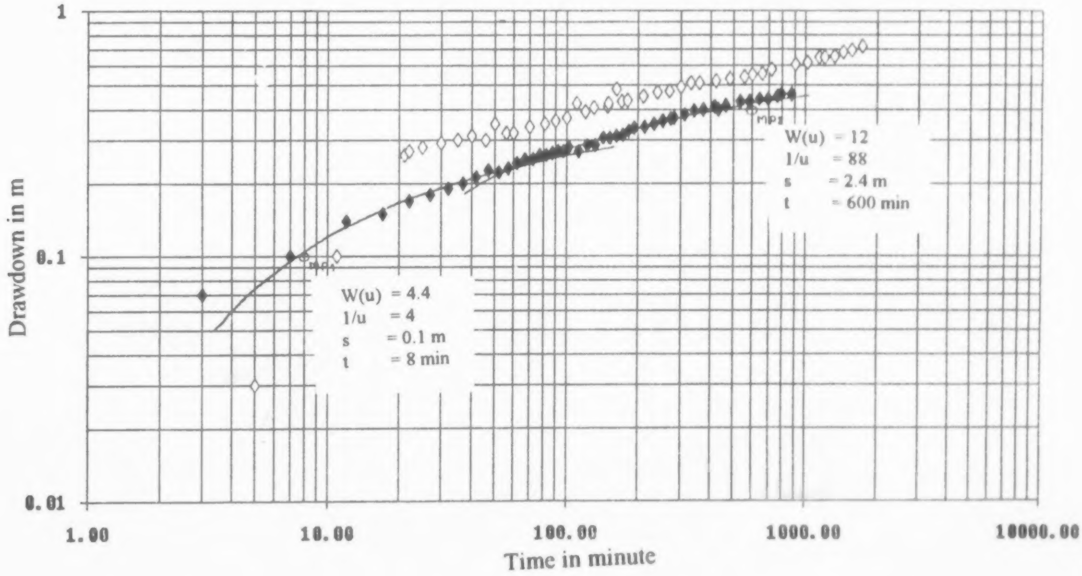
APPENDIX 4.2 THIES FITTING CURVES FOR PARTIALLY PENETRATING WELLS AND ANISOTROPIC AQUIFERS (PART 2)

PUMPING	WELL	OBS	WELL	AQUIFER								MATCH POINT								
WELL#	DEPTH	WELLNO	DEPTH	TYPE	r	l	d	lo	do	b	Kv/Kh	W(u)	1/u	s	t	Q	T	S	H(m)	Qs20
					(m)	(m)	(m)	(m)	(m)	(m)				(m)	(min)	(l/s)	(m2/s)			(l/s)
WW1	46.5			CONC.		46.50	28.90			100.00						1.72				
WW2	48.80					40.40	26.70			110.00						1.82	2.71E-03	0.0063	10	12.922338
WW2	48.80	P21	48.00		22.00	40.40	26.70	41.80	39.80	110.00	0.0001	16.00	980.00	0.40	40.00	2.28				
WW3	48.50			UNC		48.50	31.90			152.40						12.95	9.31E-03	0.3550	10	44.3895833
WW3	48.50	P1	71.20	UNC.	22.00	48.50	31.90	70.50	8.00	152.40	0.0001	3.80	6.15	0.05	8.00	13.76	1.37E-02	0.0348	10	65.2787037
WW3	48.50	DOH	48.80	UNC.	45.00	48.50	31.90	48.80	18.20	152.40						13.76				
WW4	131.10			UNC		131.10	24.38			152.40						44.65	4.54E-03	0.0015	10	21.6518519
WW4	131.10	WW3	48.50		300.00	131.10	24.38	48.50	31.90	152.40	0.0010	2.50	21.00	0.40	60.00	44.65	1.81E-03	0.0020	10	8.64189815
WW4	131.10	P1	66.70	UNC.	275.00	131.10	24.38	70.50	8.00	152.40	0.0001	1.60	5.00	0.30	40.00	44.65	2.66E-02	0.0685	10	127.086806
WW4	131.10	P2	30.00	UNC.	200.00	131.10	24.38	30.00	8.00	152.40	0.0100	3.80	250.00	0.40	40.00	44.65	4.62E-03	0.0030	10	22.0283565
WW4	131.10	P3	29.50	UNC.	170.00	131.10	24.38	29.50	8.00	152.40	0.0100	7.50	6.35	0.20	50.00	44.65	3.91E-03	0.0134	10	18.6393519
WW4	131.10	P4	24.60	UNC.	325.00	131.10	24.38	24.60	8.00	152.40						44.65	9.42E-03	0.0080	10	44.9040509
WW4	131.10	P5	30.90	UNC.	530.00	131.10	24.38	30.90	8.00	152.40						44.65	5.51E-03	0.0323	10	26.2645833
WW4	131.10	P6	22.00	UNC.	265.00	131.10	24.38	22.00	8.00	152.40						44.65				
WW4	131.10	P7	39.00	UNC.	560.00	131.10	24.38	39.00	8.00	152.40						44.65	4.77E-03	0.0006	10	22.7546296
WW4	131.10	P8	12.50	UNC.	570.00	131.10	24.38	12.50	8.00	152.40						44.65				
WW7	120.40					120.40	36.58			400.00						3.28	1.66E-03	0.0017	10	7.93587963
WW7	120.40	P19	64.20		19.00	120.40	36.58	59.50	57.50	400.00						3.28	3.45E-03	0.0004	10	16.4319444
WW7	120.40	P20	16.70		14.00	120.40	36.58	16.00	15.00	400.00	0.0100	7.00	800.00	0.20	8.00	3.28				
WW11	94.50					94.50	18.28			130.00						0.63	1.66E-04	0.0001	10	0.7900463
WW11	94.50	P32	36.50		63.00	94.50	18.28	60.00	52.00	130.00						0.63	1.76E-04	0.0001	10	0.83784722
WW11	94.50	NEWZ	18.00		56.00	94.50	18.28	18.00	12.00	130.00						0.63				
WW16	126.50			UNC.		126.50	30.50			264.00						41.16				
WW17	149.40			UNC.		149.40	24.38	60.00	58.00	188.00						1.14				
WW17	149.40	P79	60.00	UNC.	19.00	149.40	24.38			188.00	0.1000	0.89	1.83	0.20	10.00	1.14	6.45E-04	0.0010	10	3.07789352
WW18	152.40					152.40	18.29			212.00						0.85				
P4	24.60			UNC.		24.60	8.00			152.40						6.31				
PWLR	105.00					104.00	65.00			200.00						0.44				
PWLR	105.00	P74	63.30		48.00	104.00	65.00	44.50	14.50	200.00	0.0010	1.33	2000.00	0.20	300.00	0.44				
PWDF	91.00					82.40	66.00			200.00						3.85				
PWKKC	36.00					16.00	4.50			46.00						1.23				
PWTW	94.00					35.70	7.20			72.00						0.44				
PWKS	78.6					46	9			46.00						1.75				
PWKS	78.6	P11	36.6		4	46	9	13	11	46.00	0.1000	1.70	4.60	0.20	10.00					
S913	91.5					85.36	54.88			200.00										

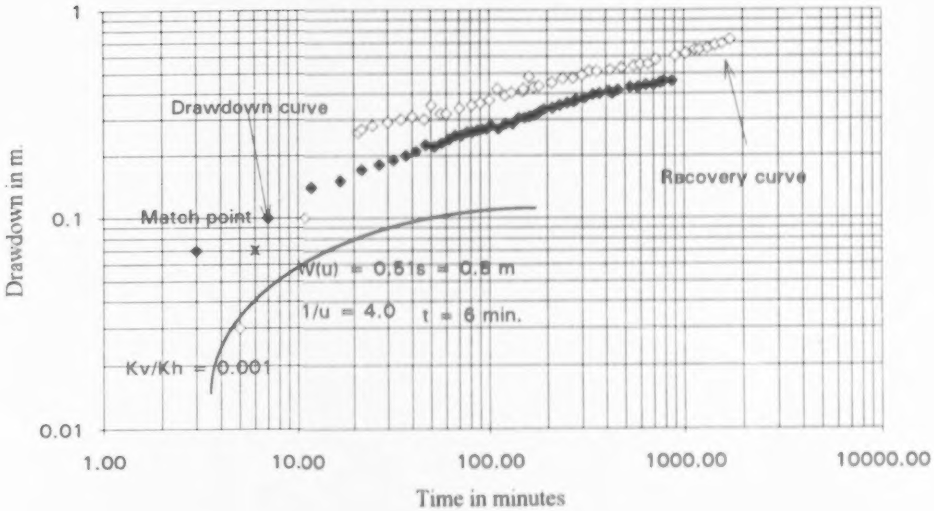
Appendix 4.3 Time drawdown curve for pumping test analysis in the Khon Kaen Drainage Basin



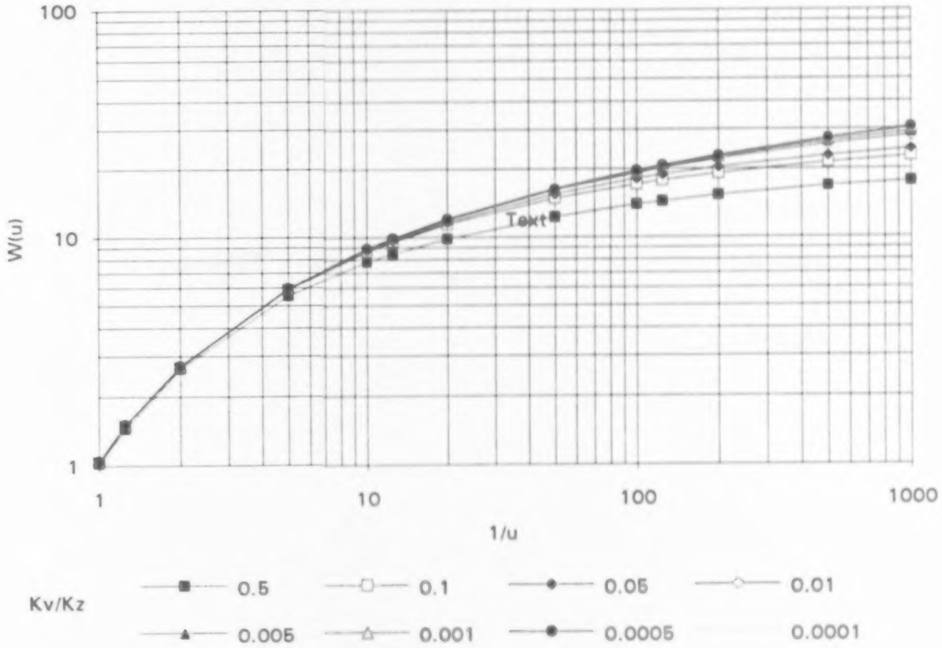
Theis fitting curve for fully penetrating and isotropic aquifer of well P19 due to pumping well WW7



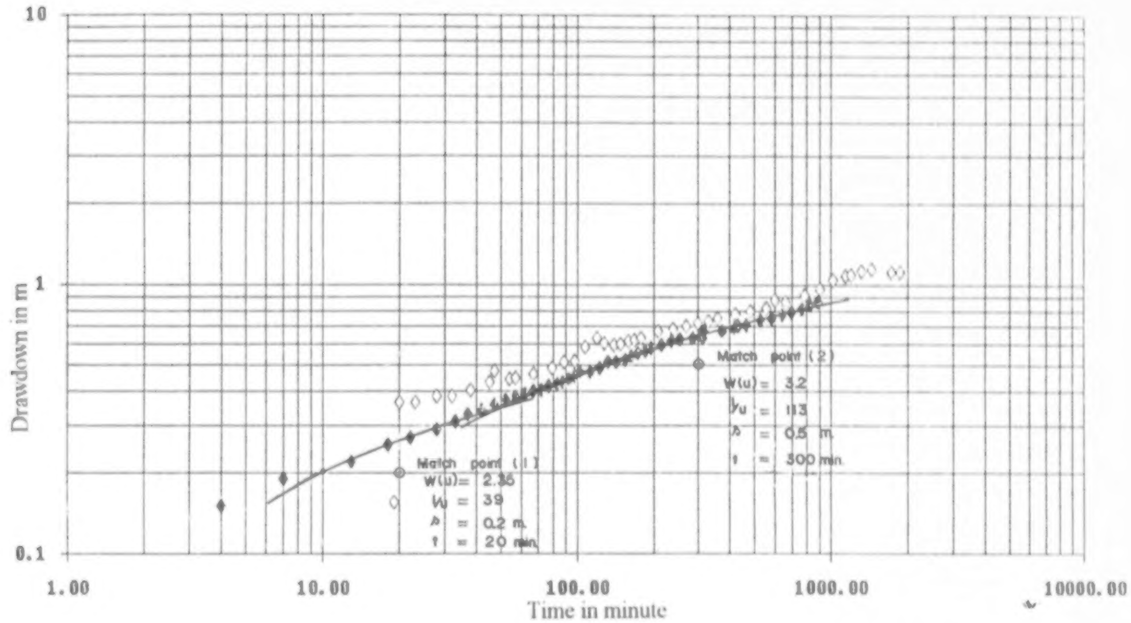
Theis fitting curve for partially penetrating and isotropic aquifer of well P19 due to pumping well WW7



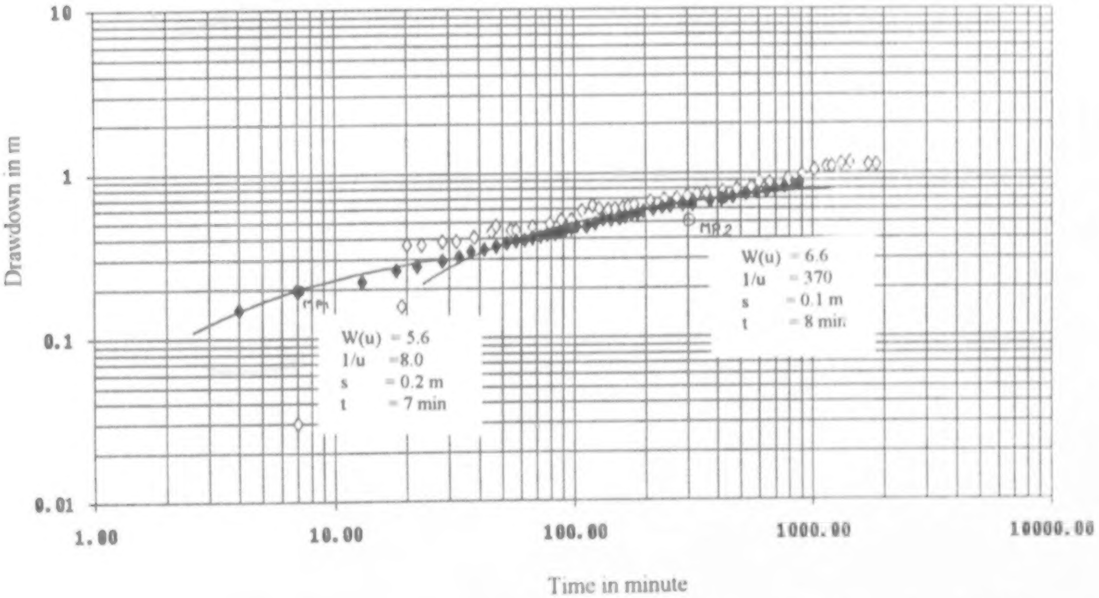
Theis fitting curve for partially penetrating and anisotropic aquifer of well P19 due to pumping well WW7



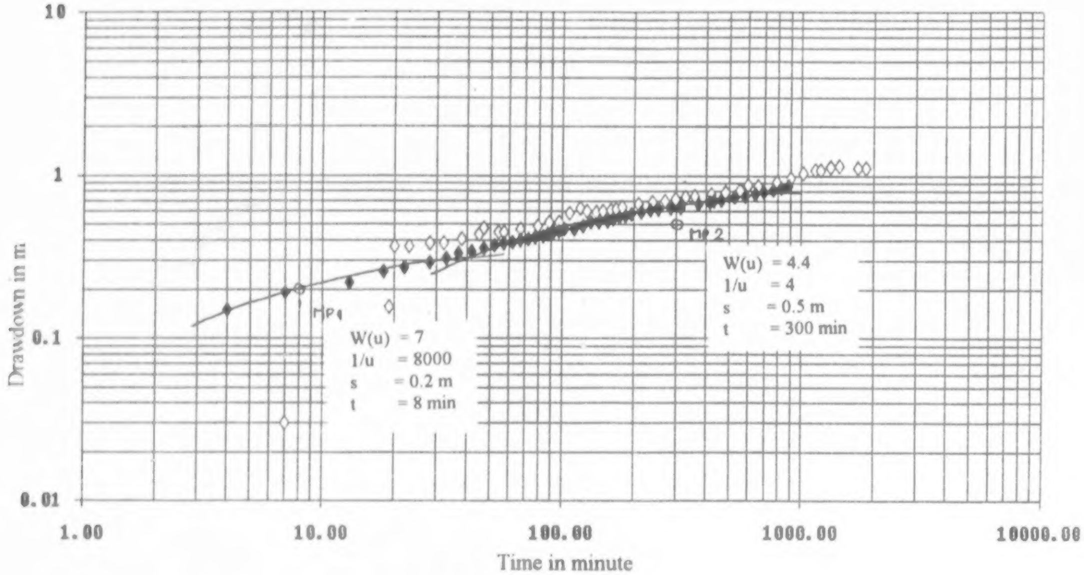
Master curve for fully penetrating and anisotropic aquifer of well P19 due to pumping well WW7



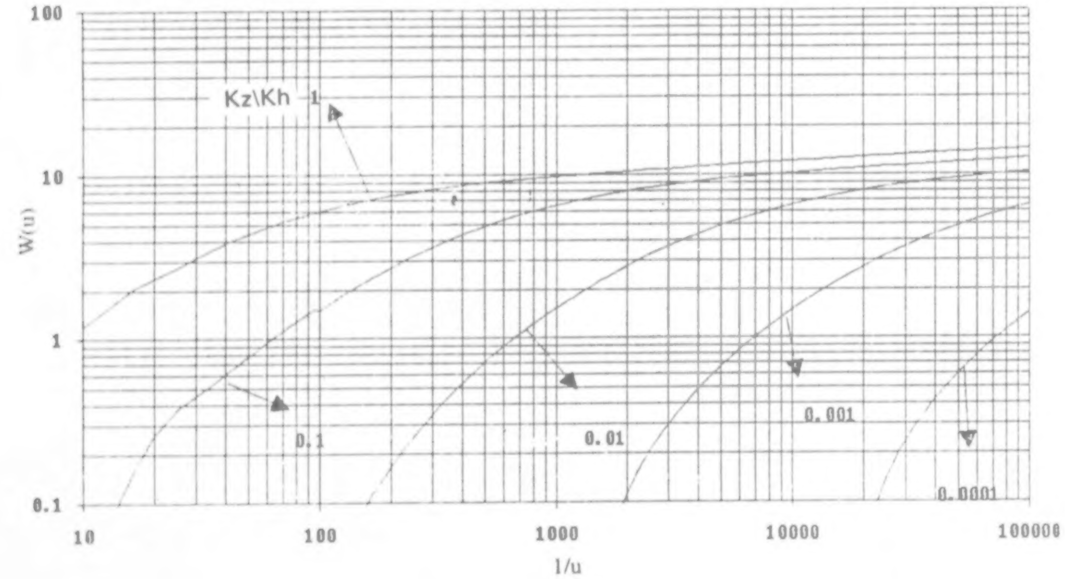
Theis fitting curve for fully penetrating and isotropic aquifer of well P20 due to pumping well WW7



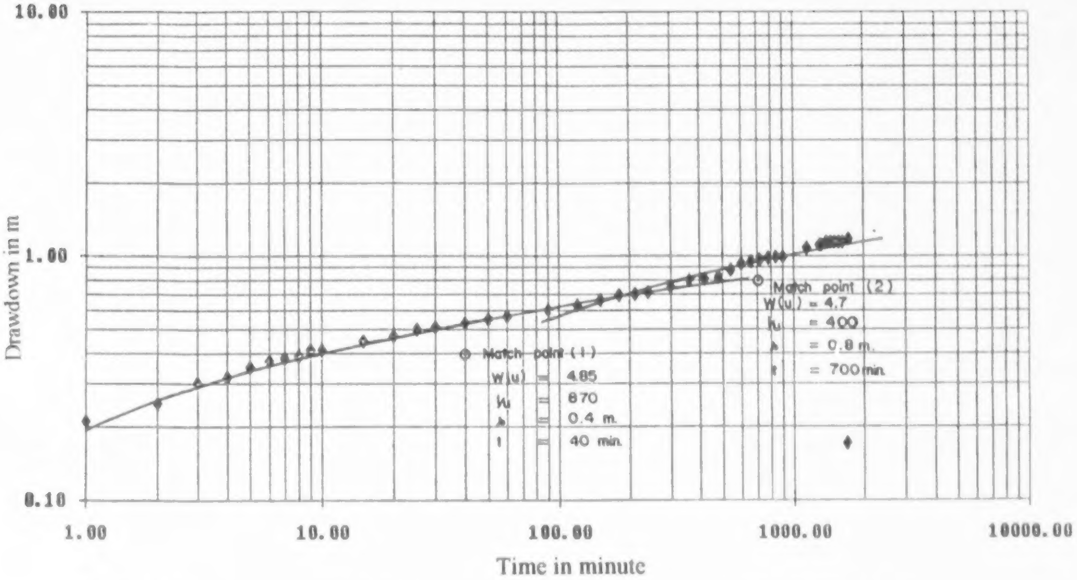
Theis fitting curve for partially penetrating and isotropic aquifer of well P20 due to pumping well WW7



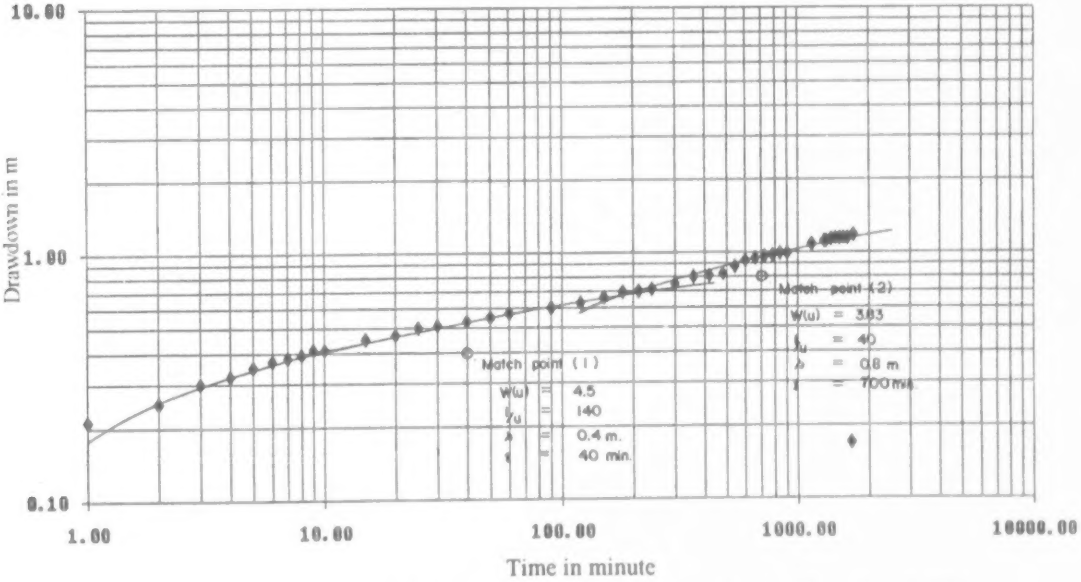
Theis fitting curve for partially penetrating and anisotropic aquifer of well P20
due to pumping well WW7



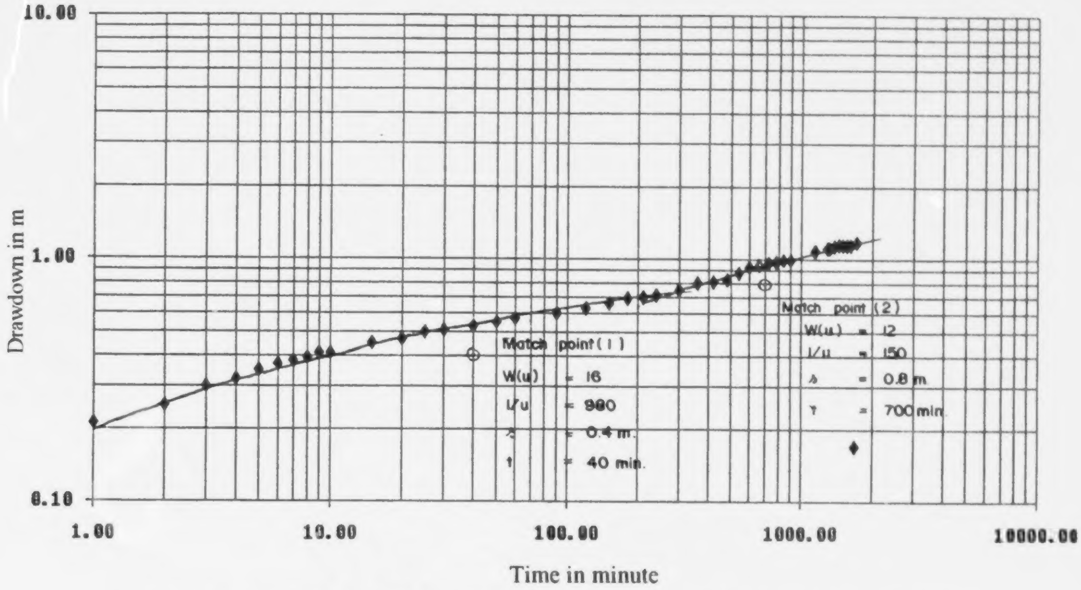
Master curve for fully penetrating and anisotropic aquifer of well P20
due to pumping well WW7



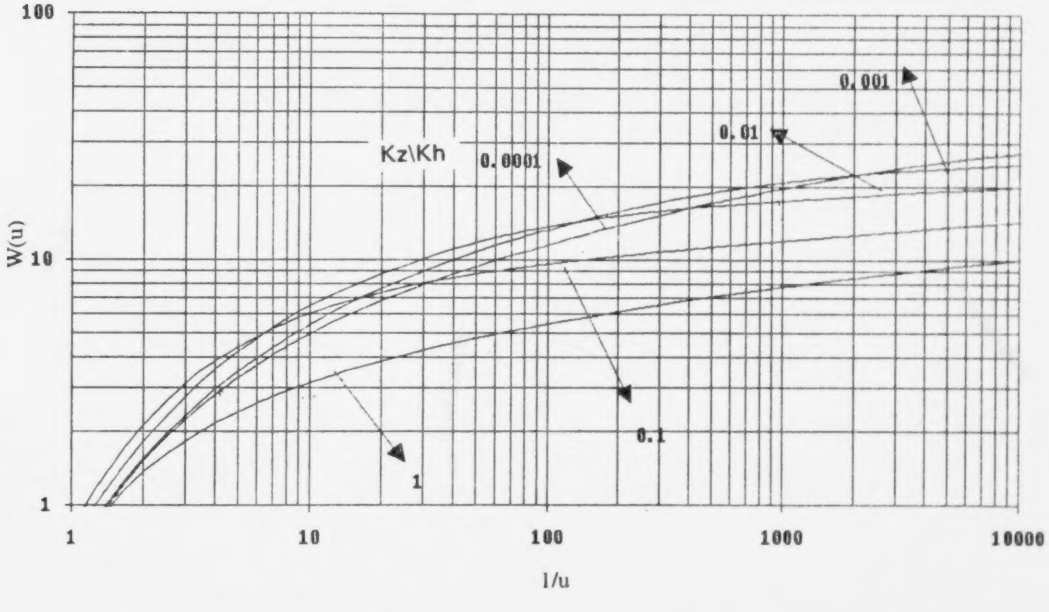
Theis fitting curve for fully penetrating and isotropic aquifer of well P21 due to pumping well WW2



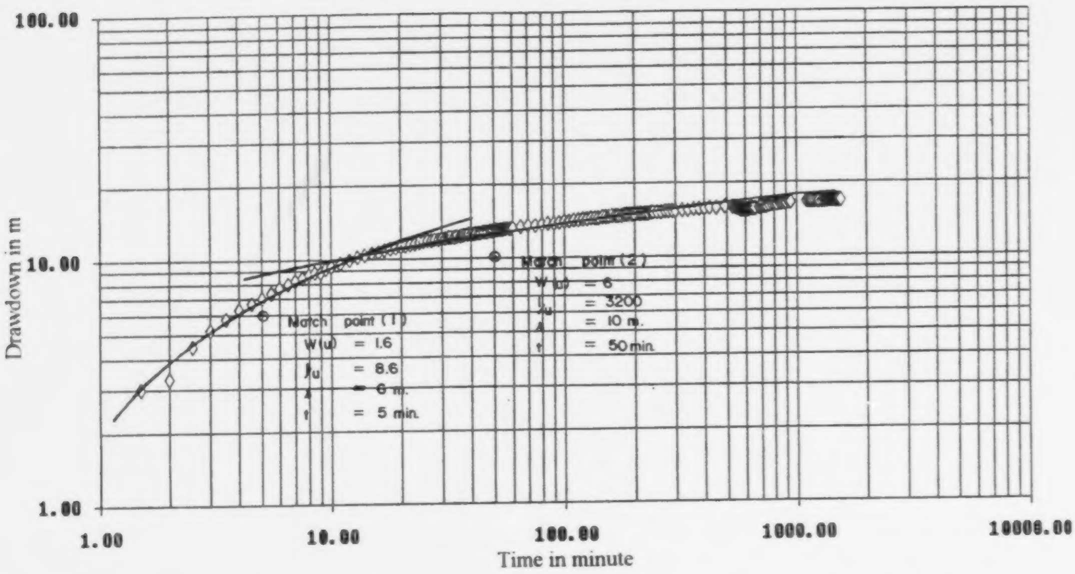
Theis fitting curve for partially penetrating and isotropic aquifer of well P21 due to pumping well WW2



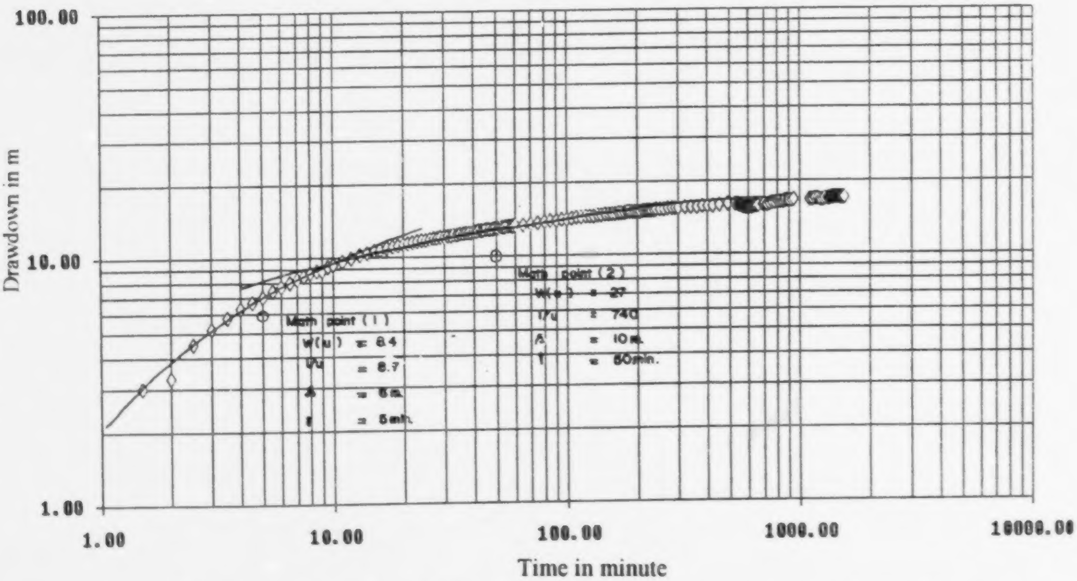
Theis fitting curve for fully penetrating and anisotropic aquifer of well P21
due to pumping well WW2



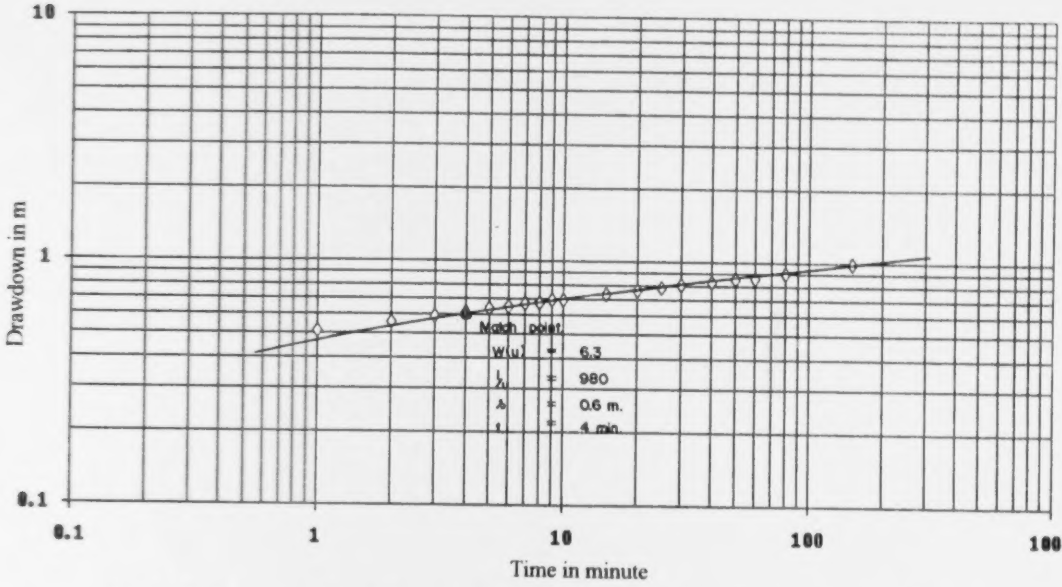
Master curve for partially penetrating and anisotropic aquifer of well P21
due to pumping well WW2



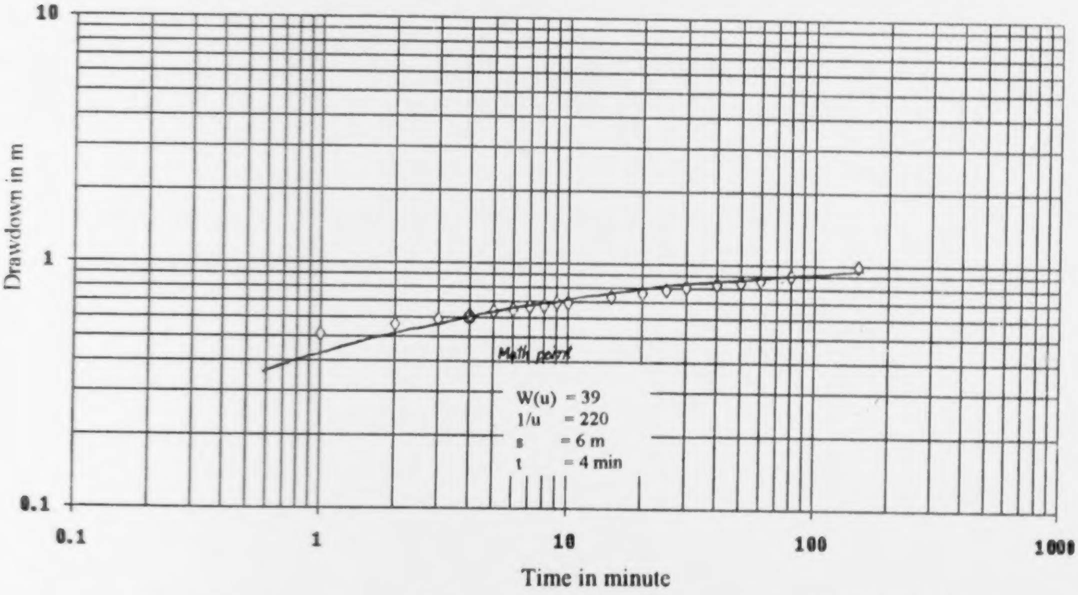
Theis fitting curve for fully penetrating and isotropic aquifer of well WW1 due to pumping well WW1



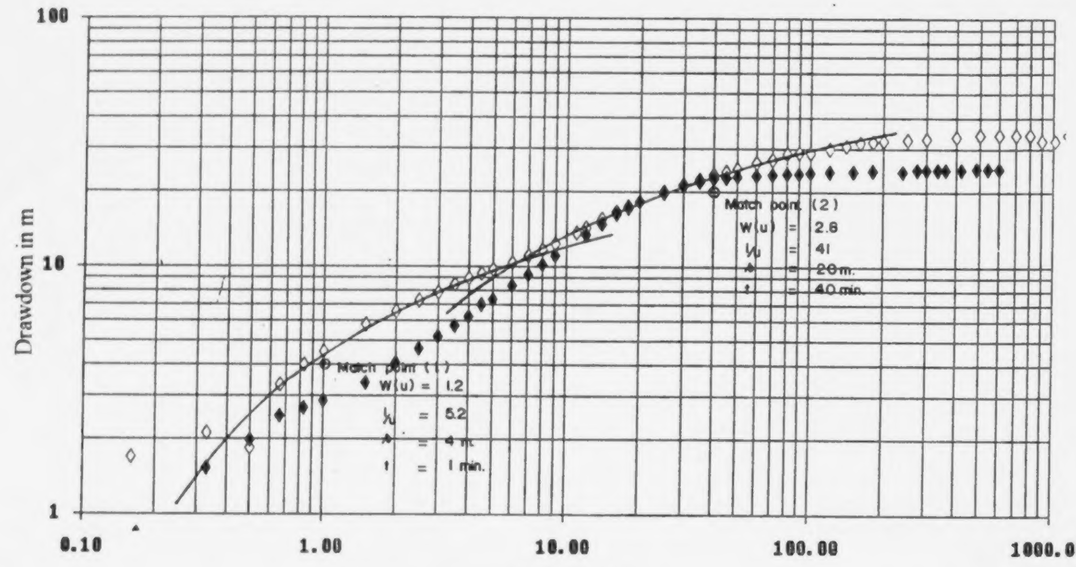
Theis fitting curve for partially penetrating and isotropic aquifer of well WW1 due to pumping well WW1



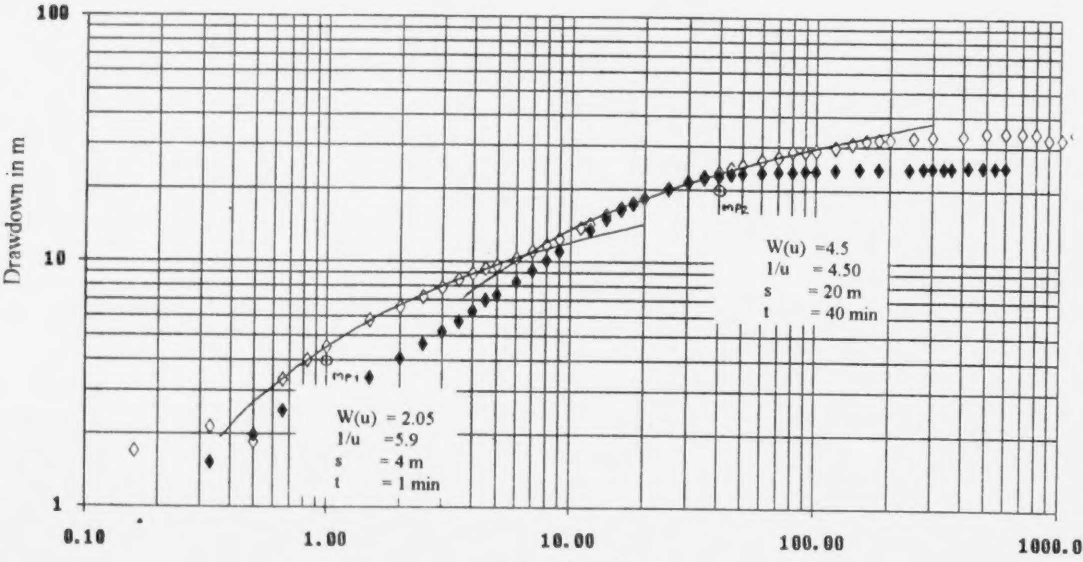
Theis fitting curve for fully penetrating and isotropic aquifer of well WW2 due to pumping well WW2



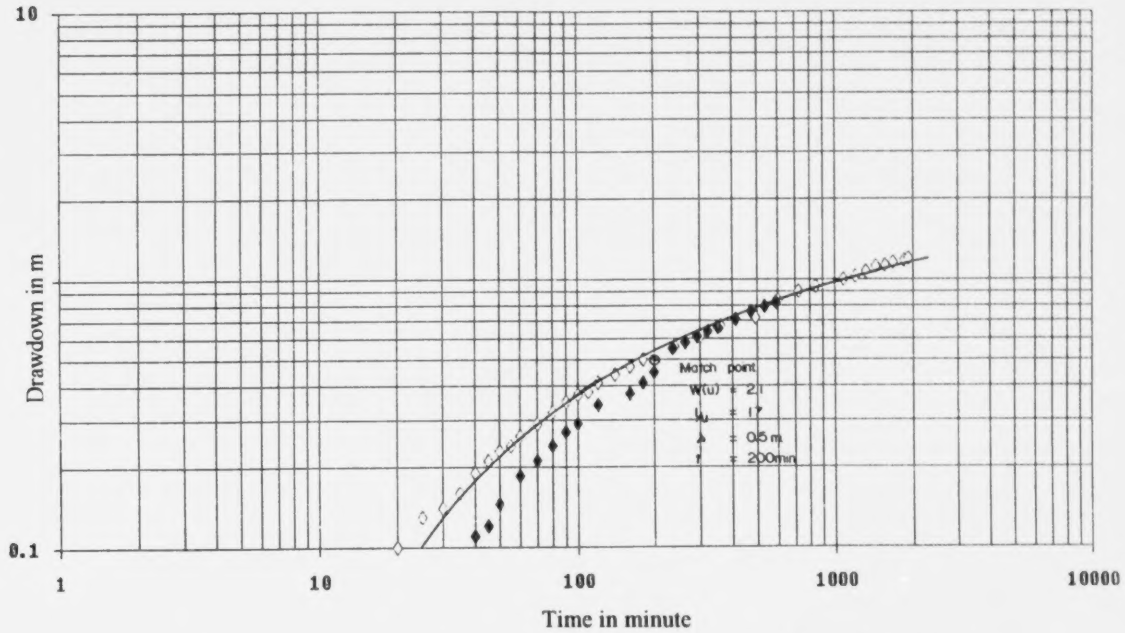
Theis fitting curve for partially penetrating and isotropic aquifer of well WW2 due to pumping well WW2



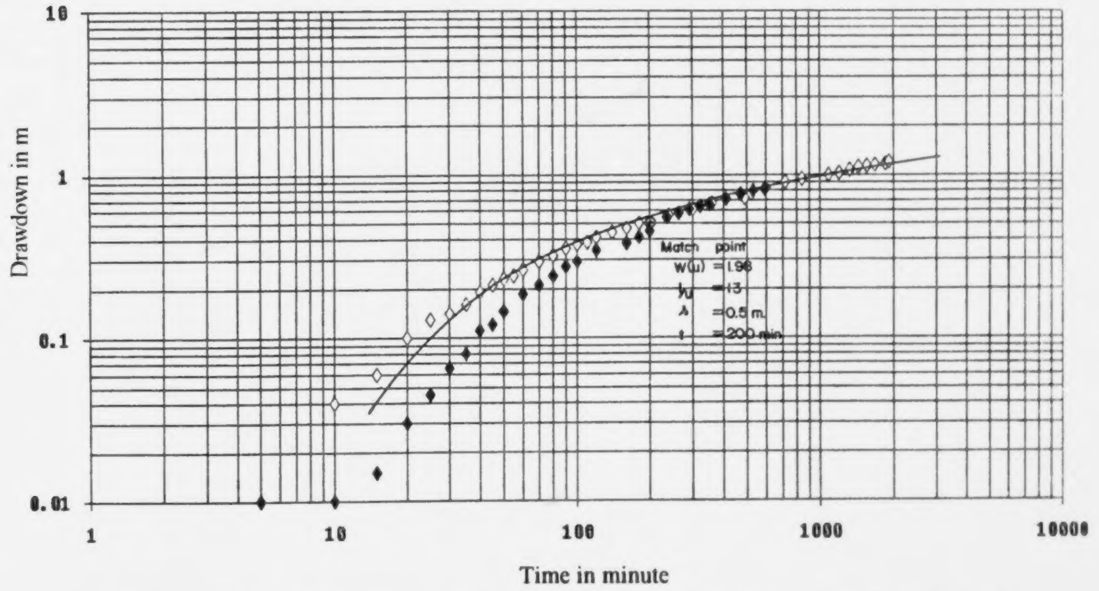
Theis fitting curve for fully penetrating and isotropic aquifer of well WW11 due to pumping well WW11



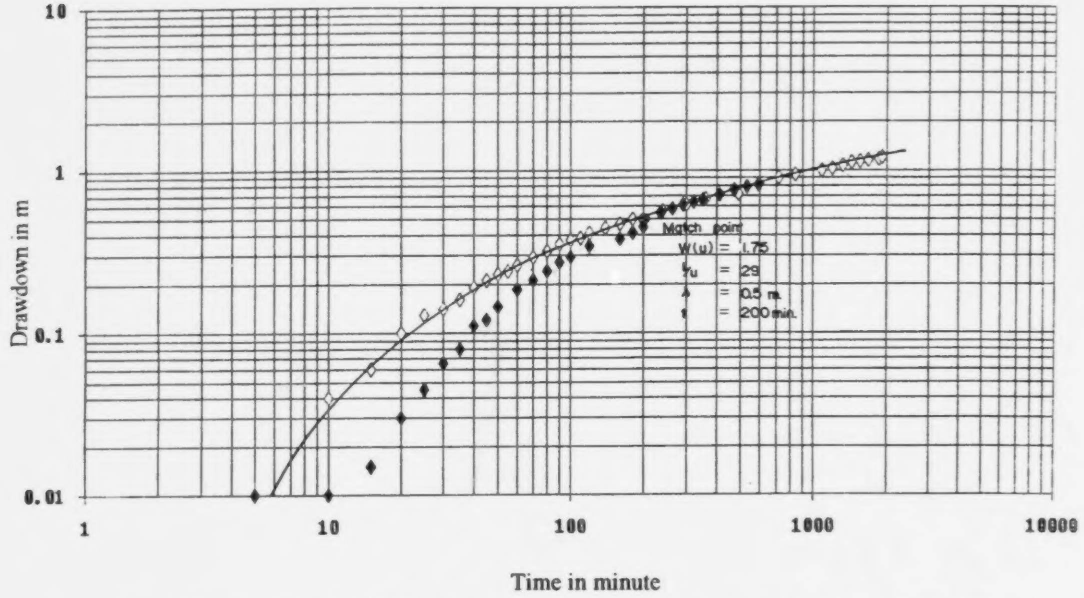
Theis fitting curve for partially penetrating and isotropic aquifer of well WW11 due to pumping well WW11



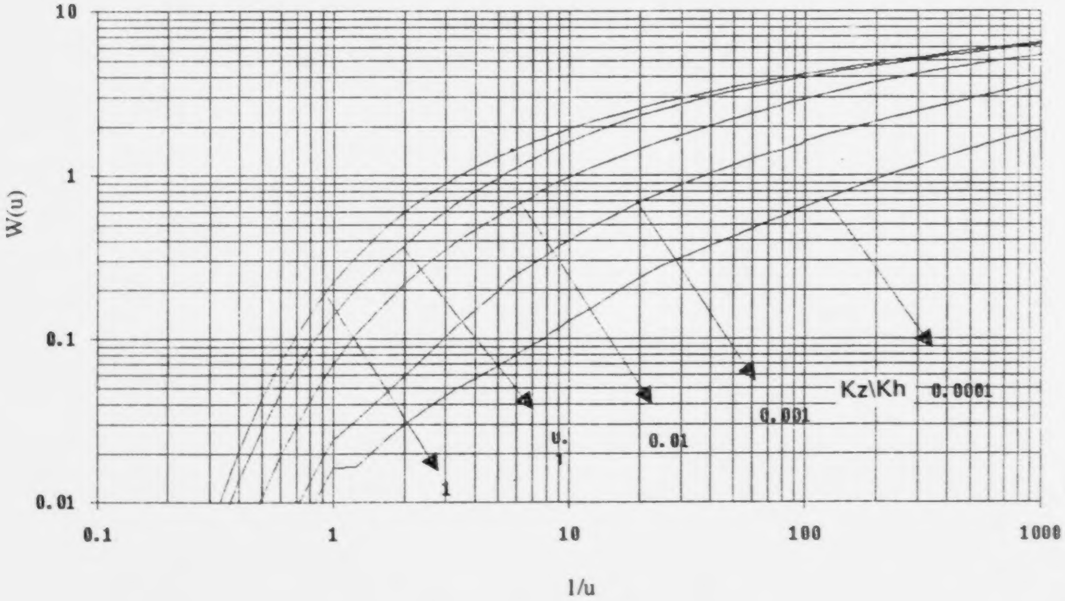
Theis fitting curve for fully penetrating and isotropic aquifer of well PWNZ due to pumping well WW11



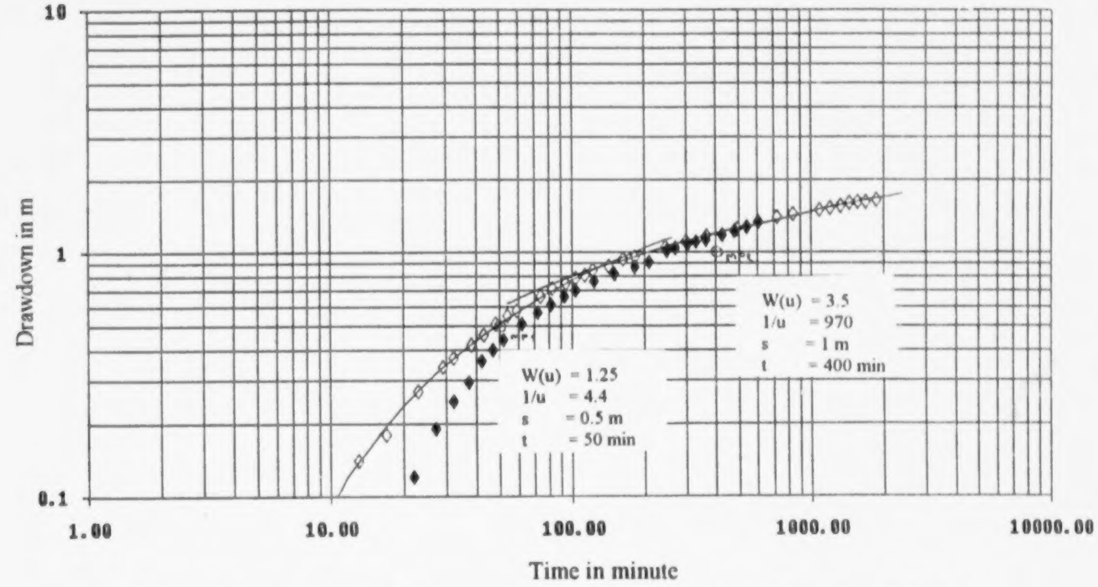
Theis fitting curve for partially penetrating and isotropic aquifer of well PWNZ due to pumping well WW11



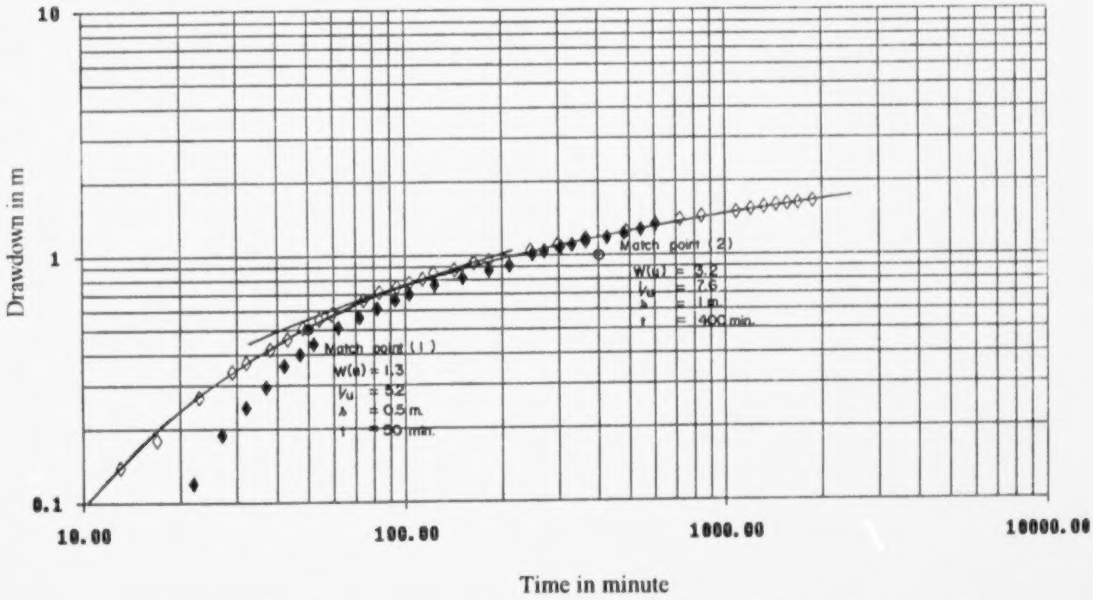
Theis fitting curve for fully penetrating and anisotropic aquifer of well PWNZ due to pumping well WW11



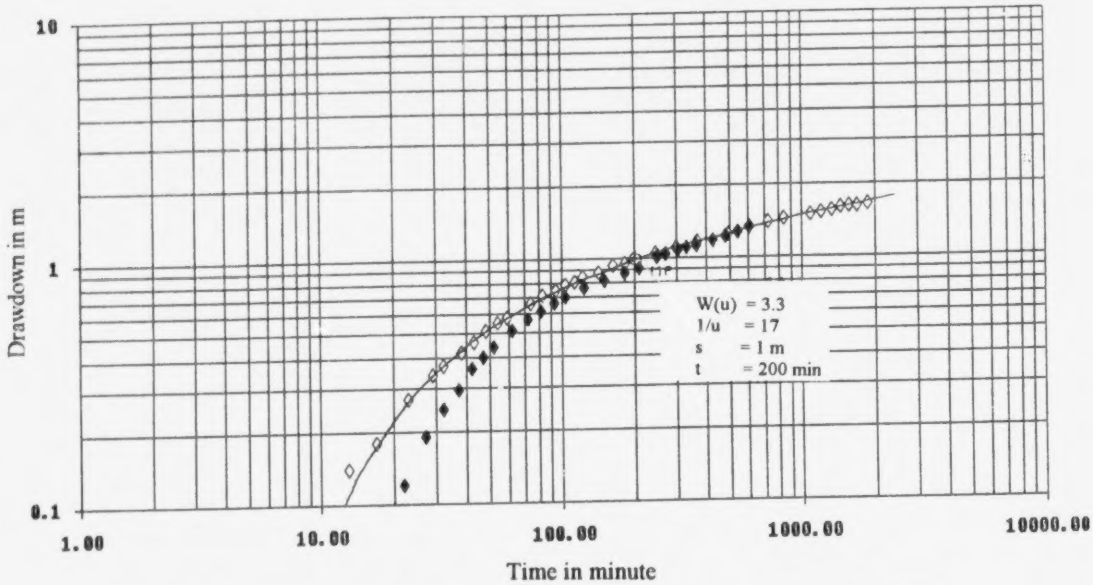
Master curve for partially penetrating and anisotropic aquifer of well PWNZ due to pumping well WW11



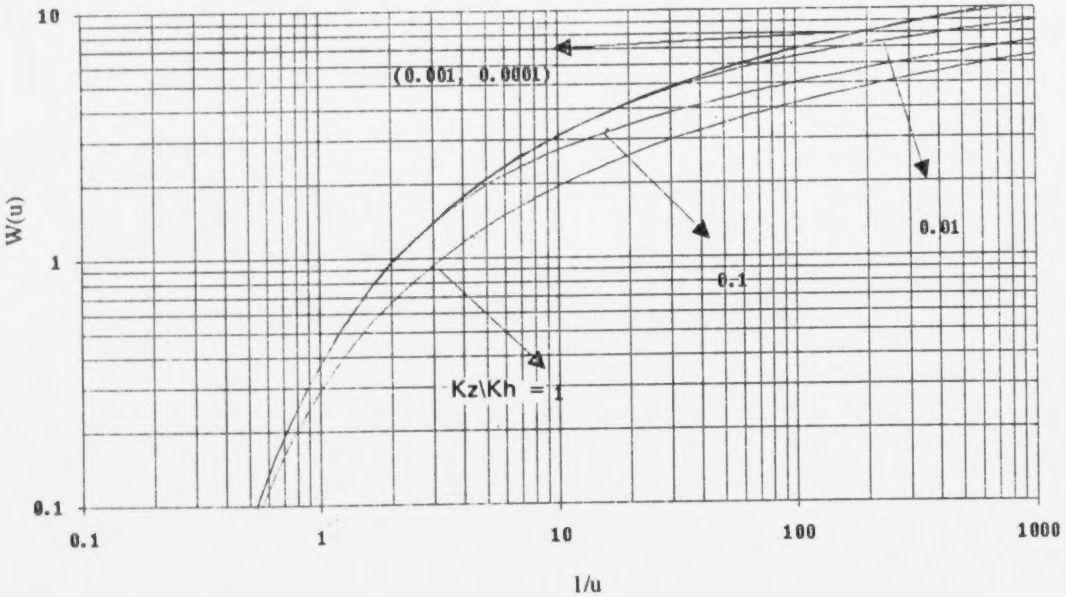
Theis fitting curve for fully penetrating and isotropic aquifer of well P32 due to pumping well WW16



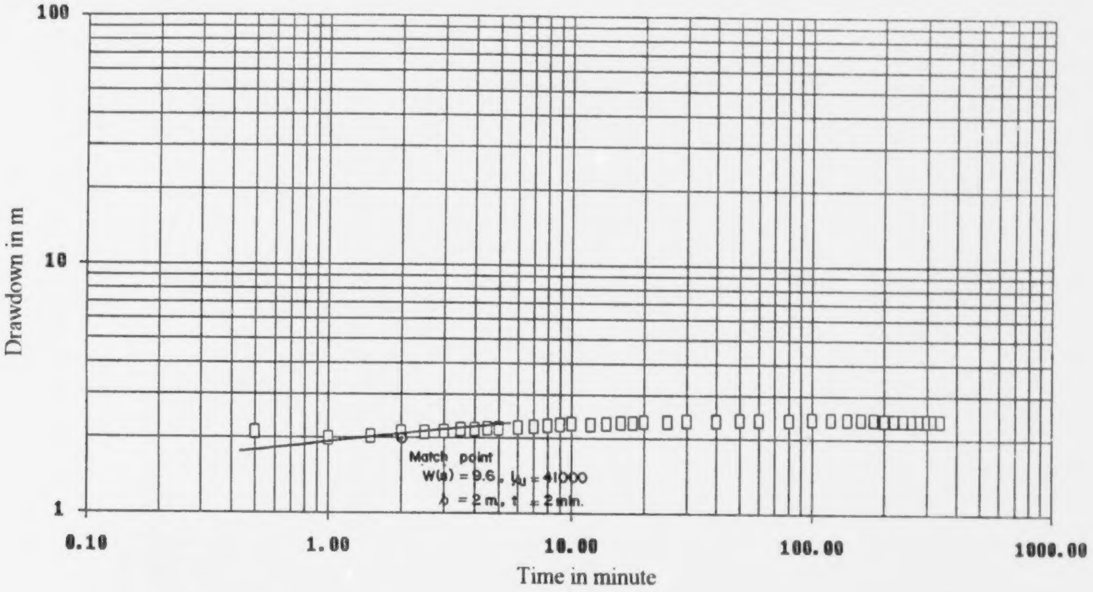
Theis fitting curve for partially penetrating and isotropic aquifer of well PWNZ due to pumping well WW11



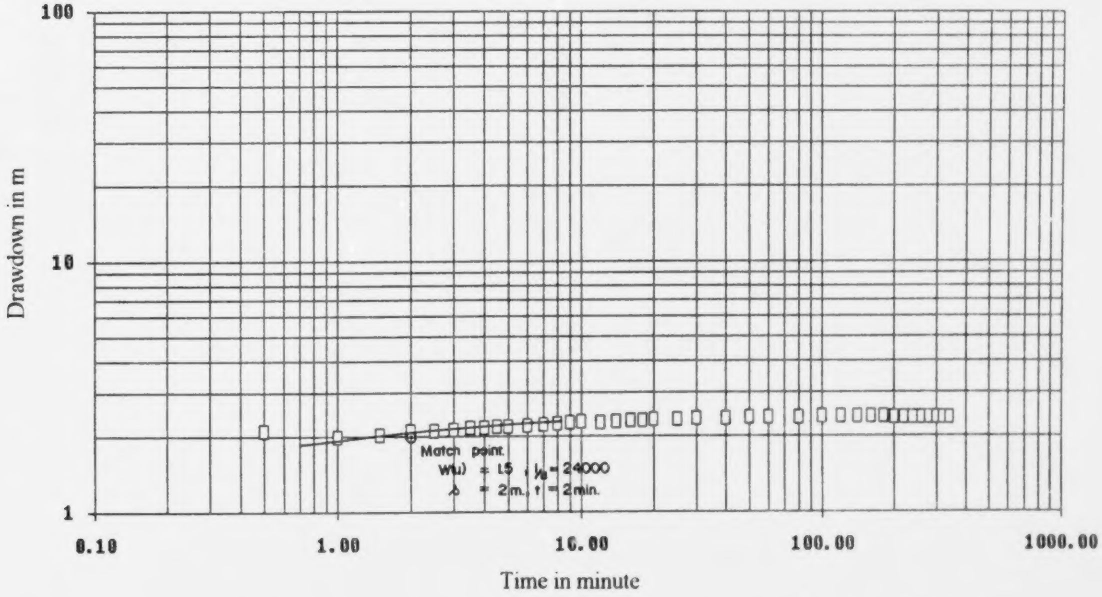
Theis fitting curve for fully penetrating and anisotropic aquifer of well P32 due to pumping well WW16



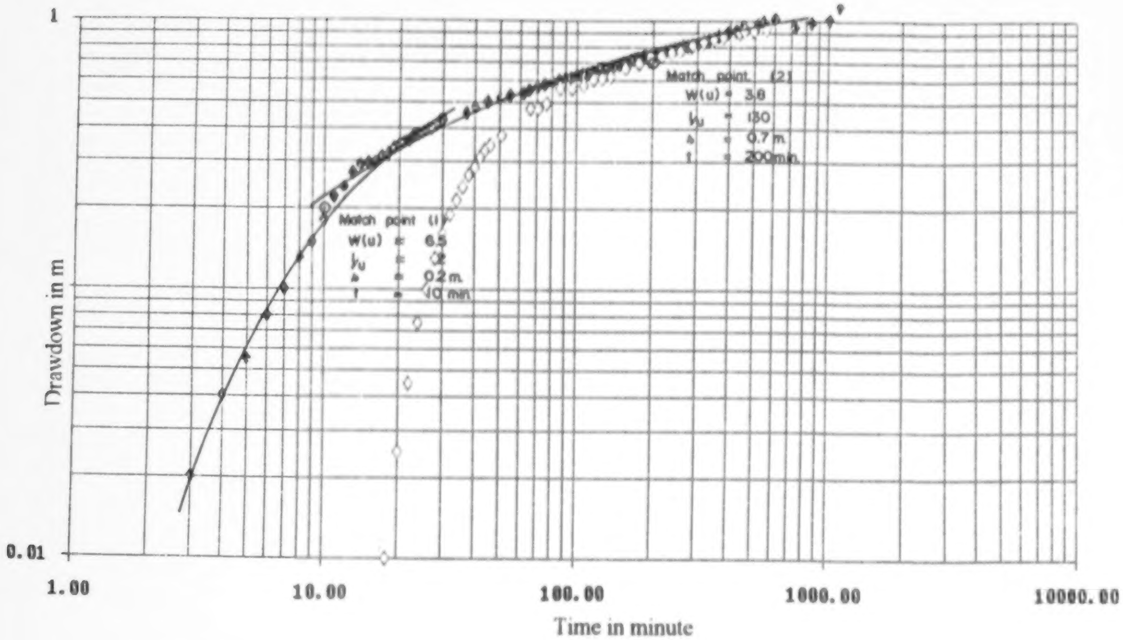
Master curve for partially penetrating and anisotropic aquifer of well PWNZ due to pumping well WW11



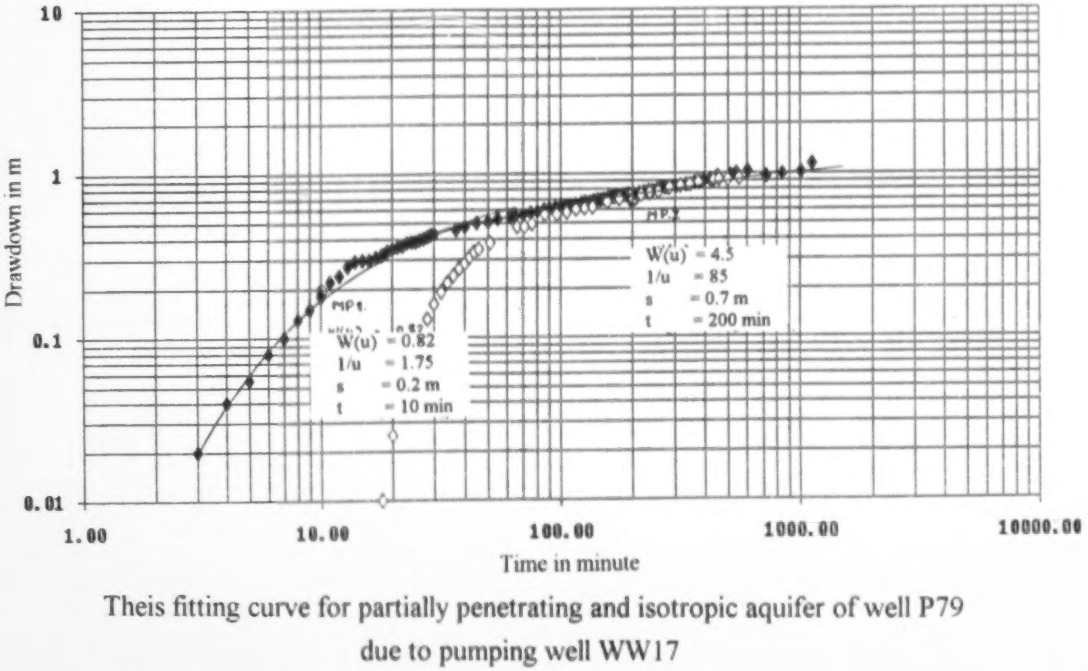
Theis fitting curve for fully penetrating and isotropic aquifer of well WW16 due to pumping well WW16



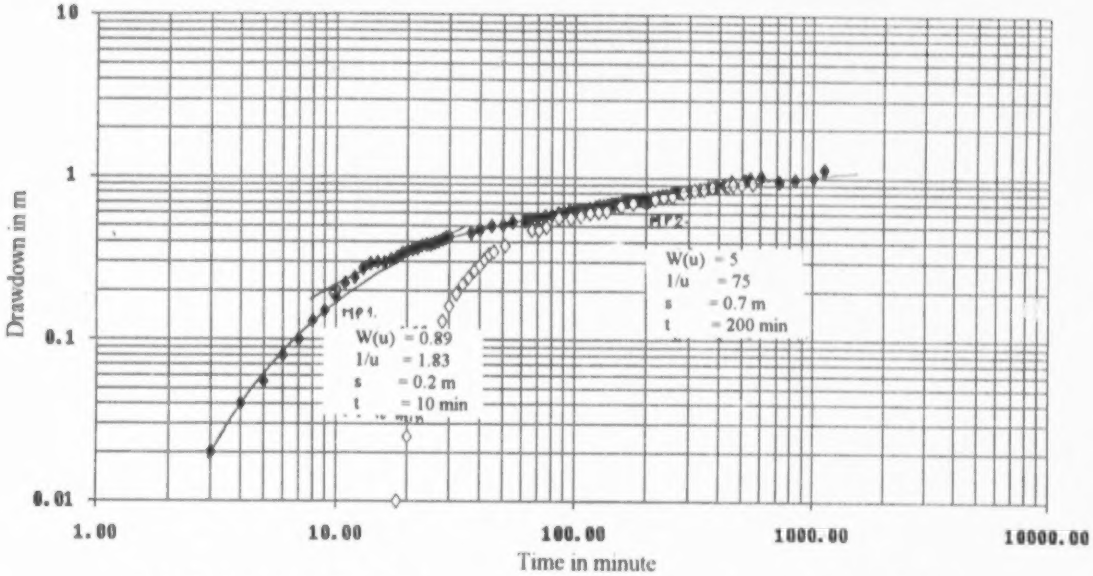
Theis fitting curve for partially penetrating and isotropic aquifer of well WW16 due to pumping well WW16



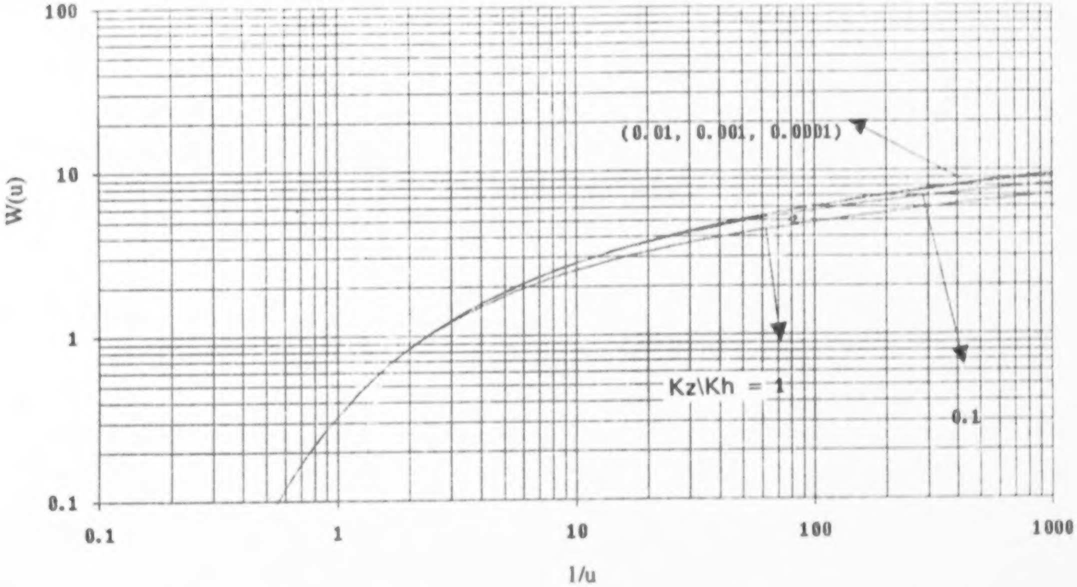
Theis fitting curve for fully penetrating and isotropic aquifer of well P79 due to pumping well WW17



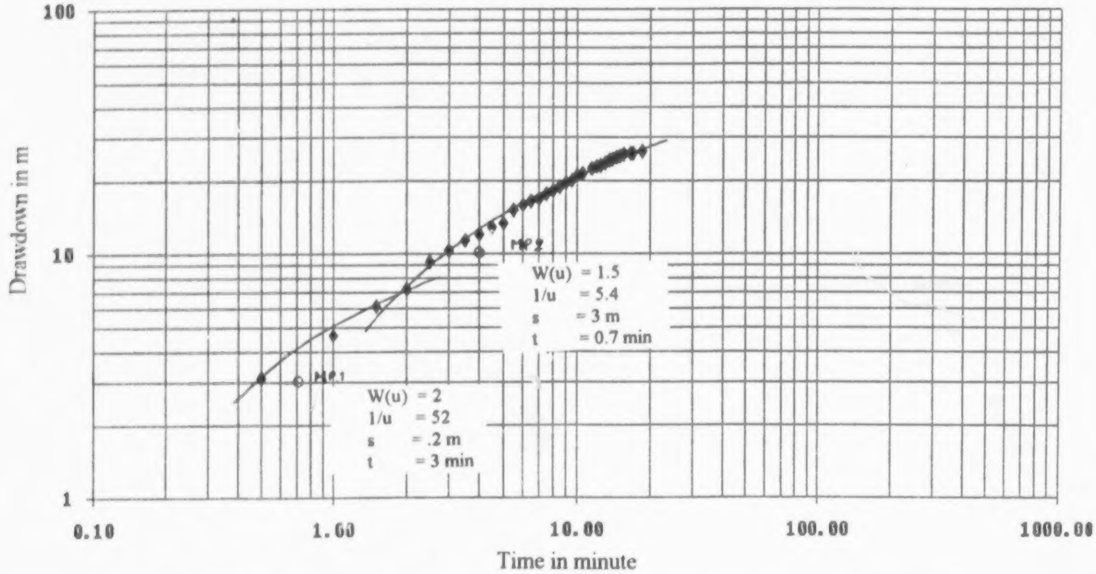
Theis fitting curve for partially penetrating and isotropic aquifer of well P79 due to pumping well WW17



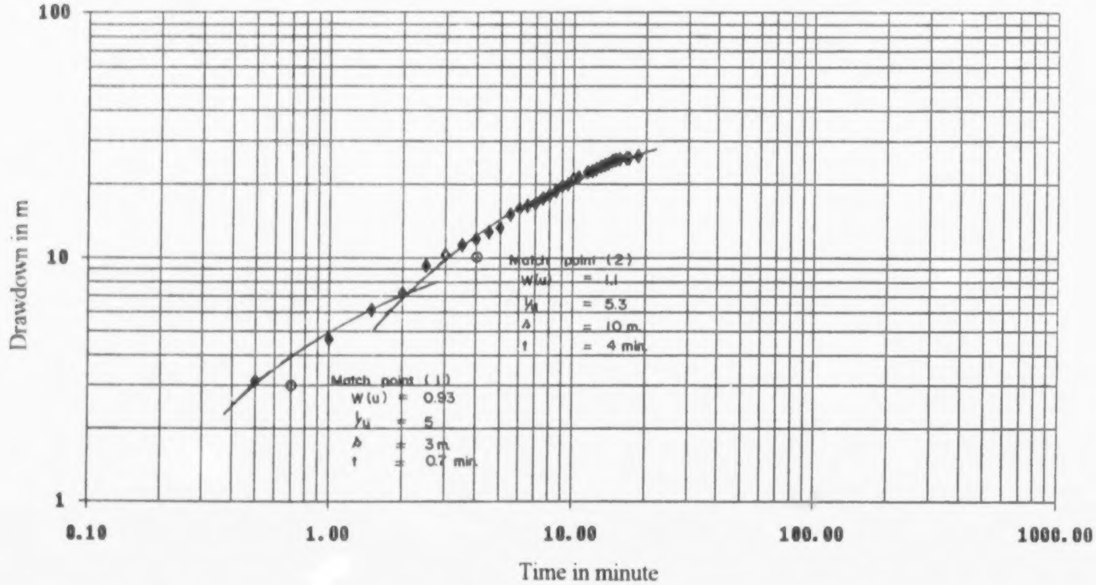
Theis fitting curve for fully penetrating and anisotropic aquifer of well P79 due to pumping well WW17



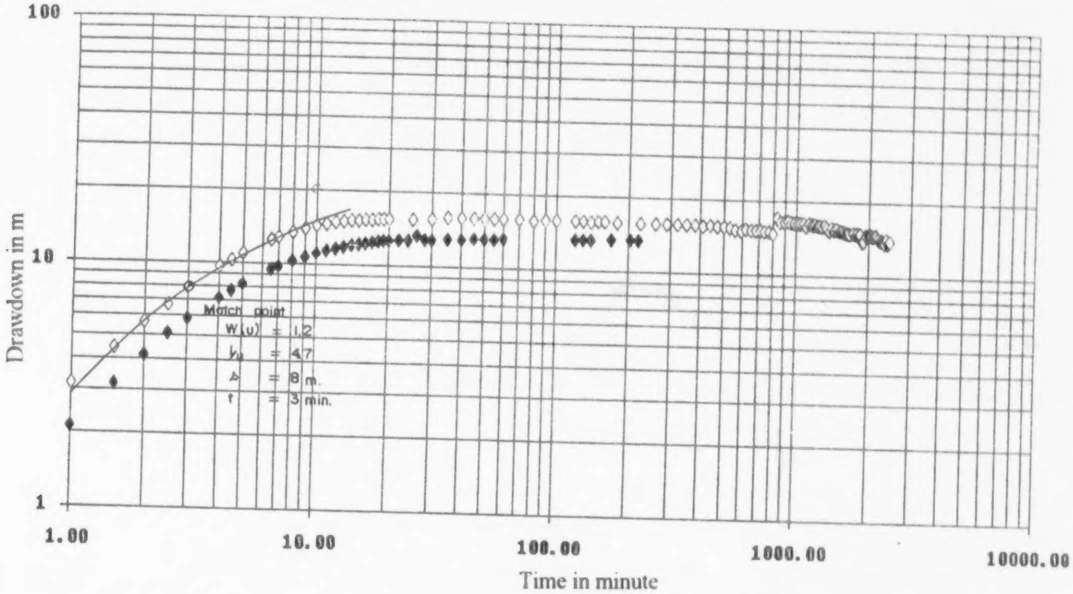
Master curve for partially penetrating and anisotropic aquifer of well P79 due to pumping well WW17



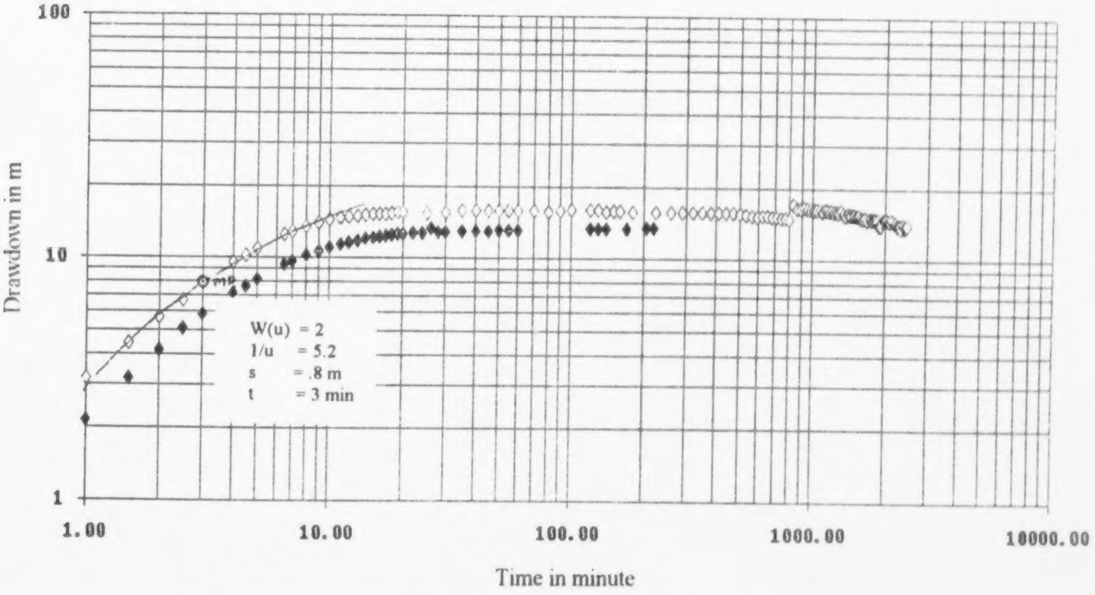
Theis fitting curve for fully penetrating and isotropic aquifer of well WW17 due to pumping well WW17



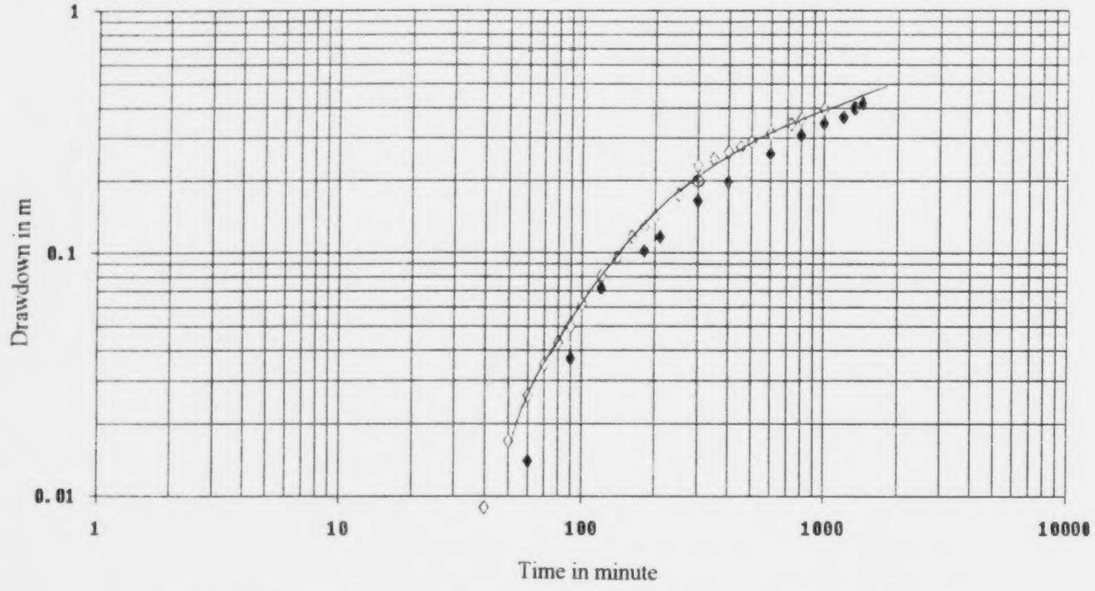
Theis fitting curve for partially penetrating and isotropic aquifer of well WW17 due to pumping well WW17



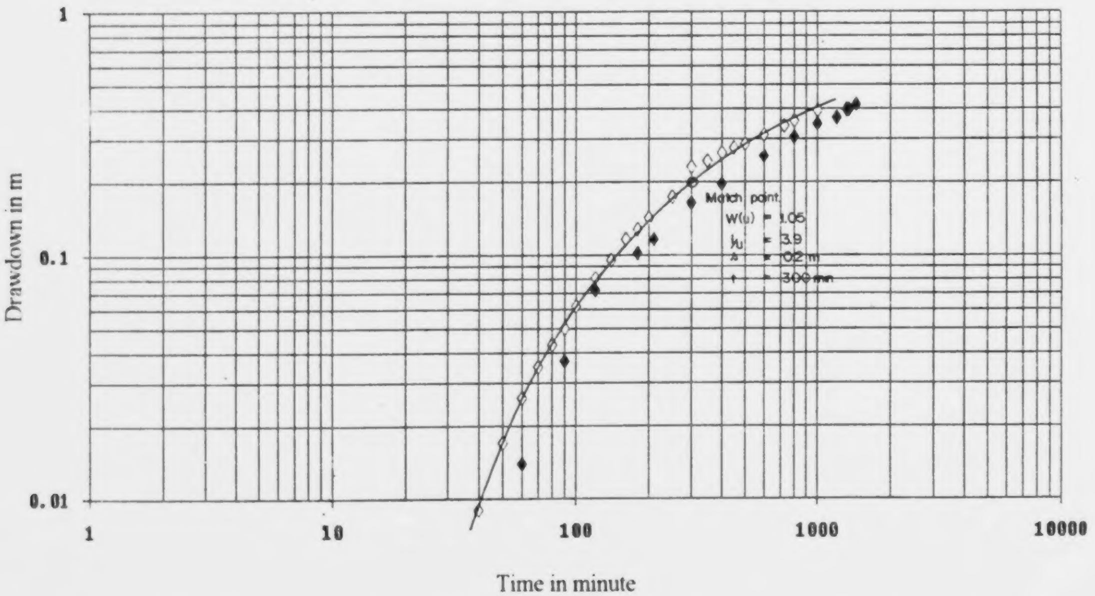
Theis fitting curve for fully penetrating and isotropic aquifer of well WW18
due to pumping well WW18



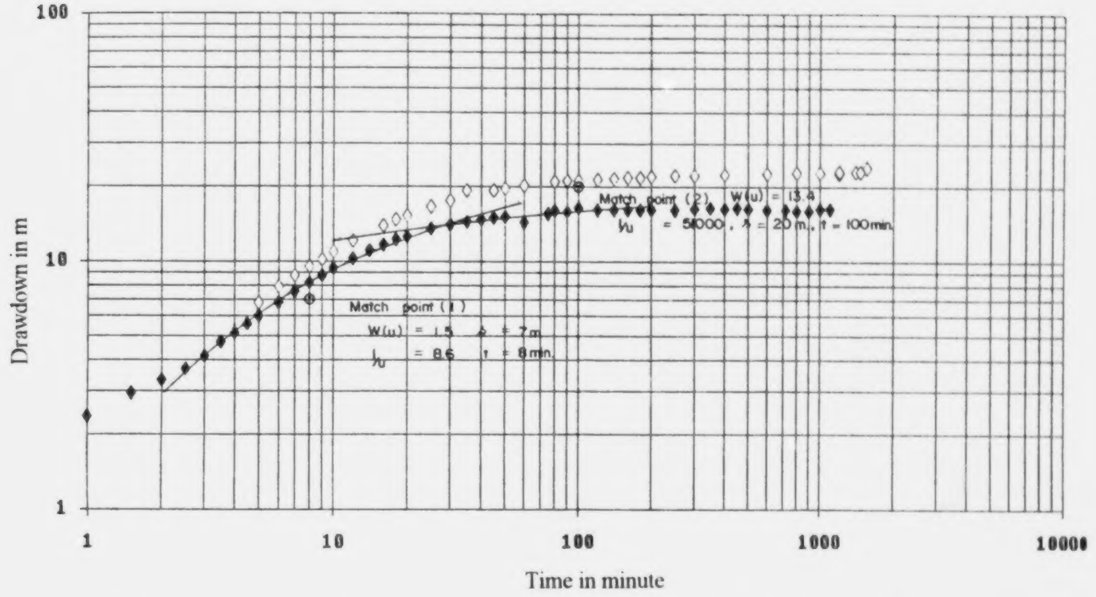
Theis fitting curve for partially penetrating and isotropic aquifer of well WW18
due to pumping well WW18



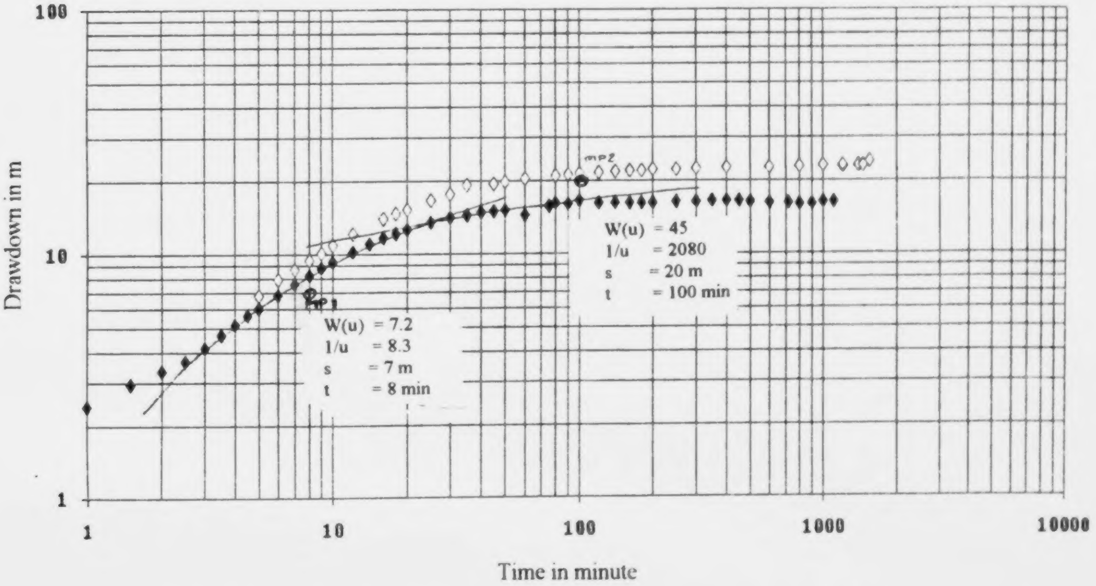
Theis fitting curve for fully penetrating and isotropic aquifer of well P74 due to pumping well PWLR



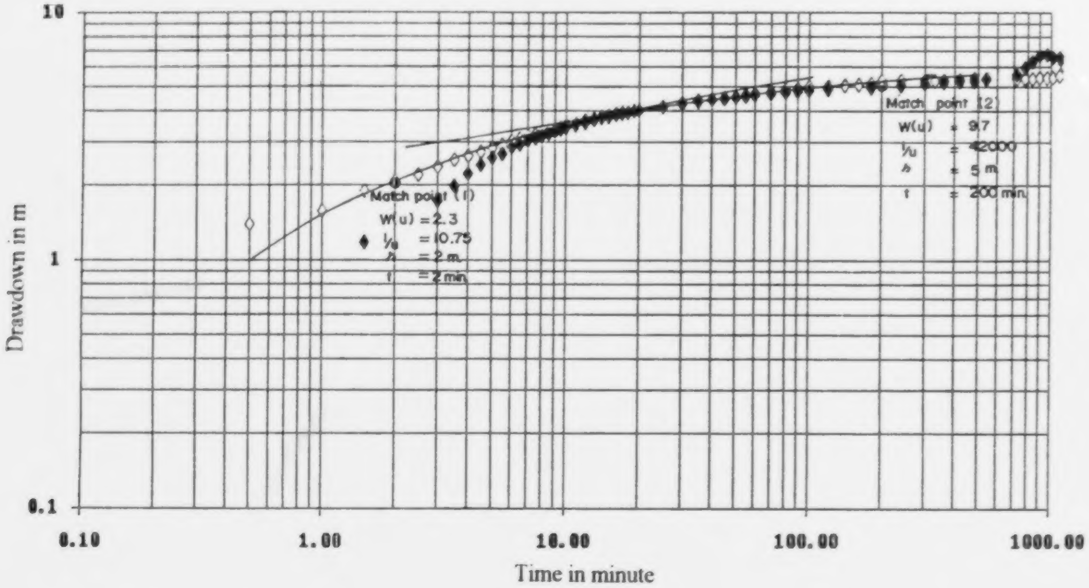
Theis fitting curve for partially penetrating and isotropic aquifer of well P74 due to pumping well PWLR



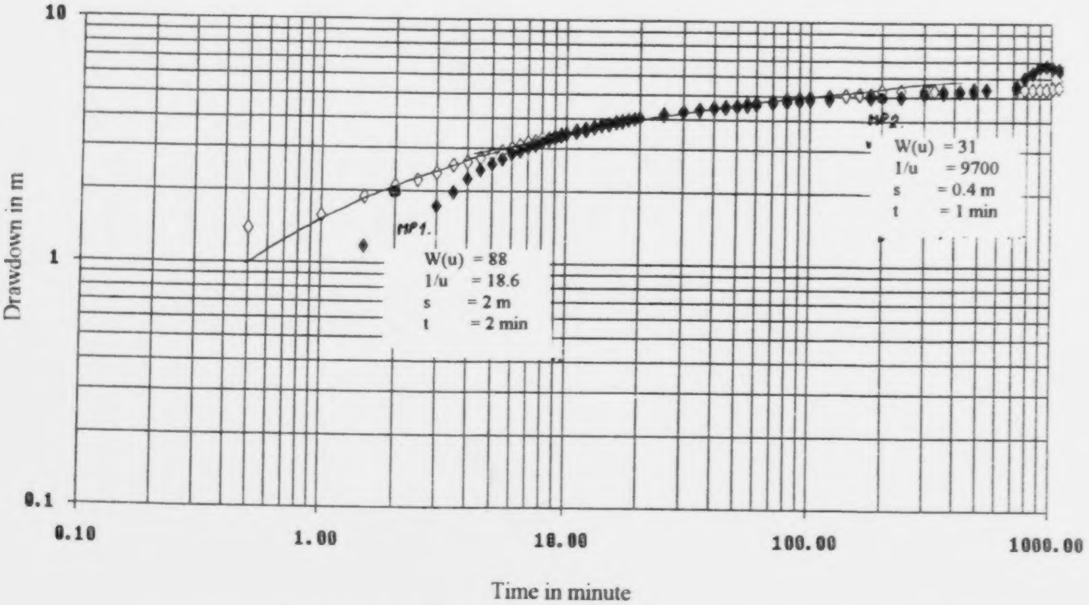
Theis fitting curve for fully penetrating and isotropic aquifer of well PWLR due to pumping well PWLR



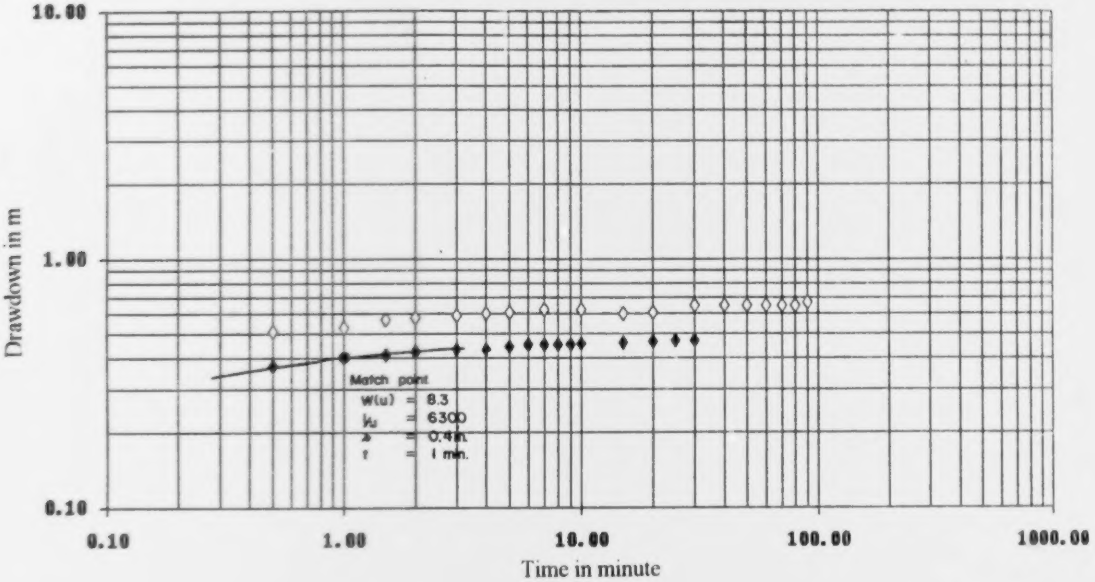
Theis fitting curve for partially penetrating and isotropic aquifer of well PWLR due to pumping well PWLR



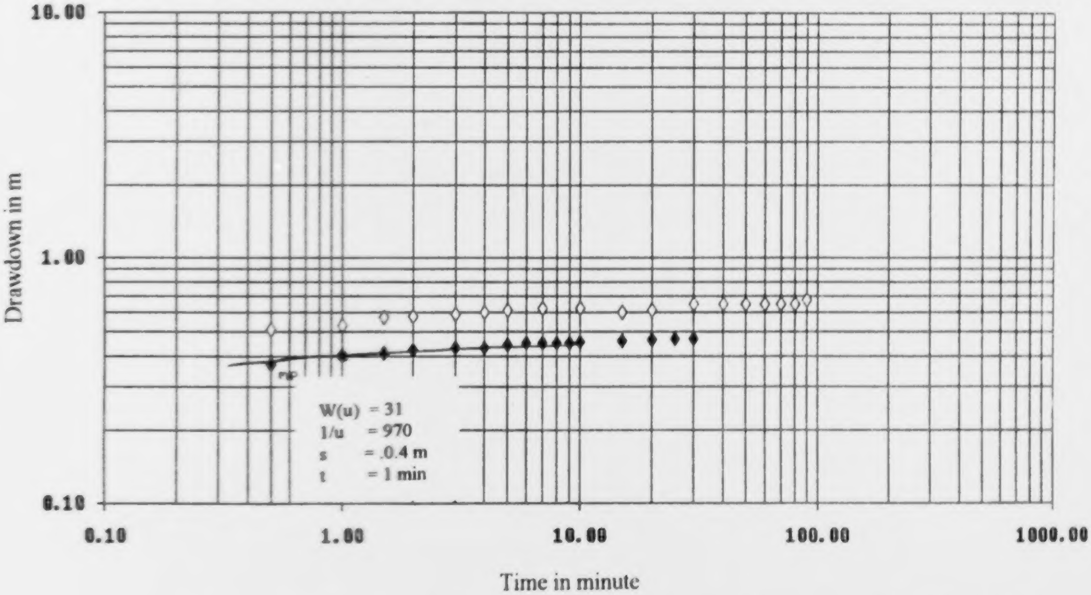
Theis fitting curve for fully penetrating and isotropic aquifer of well PWDF due to pumping well PWDF



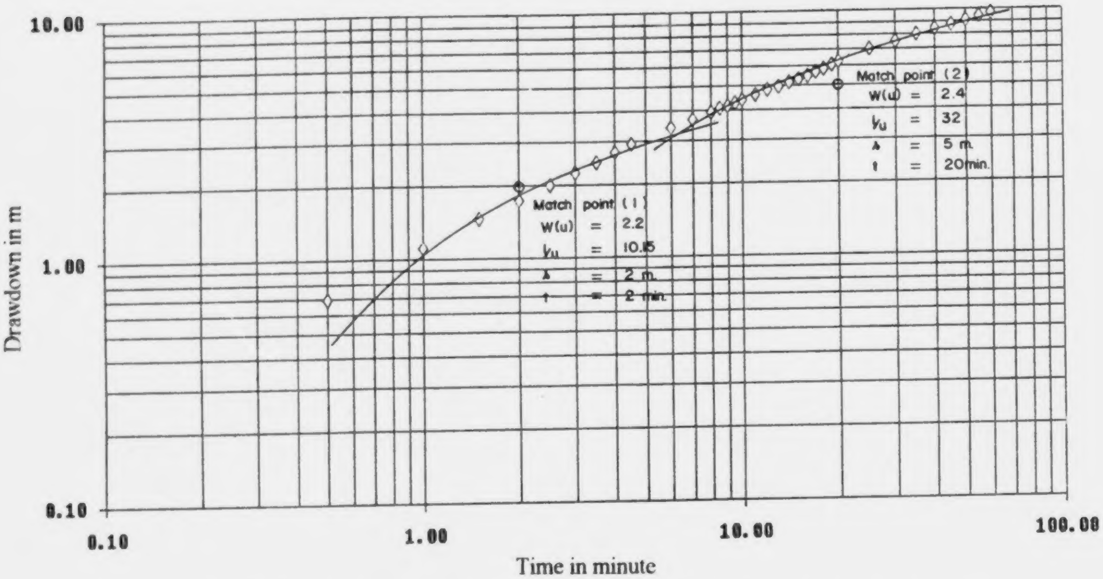
Theis fitting curve for partially penetrating and isotropic aquifer of well PWDF due to pumping well PWDF



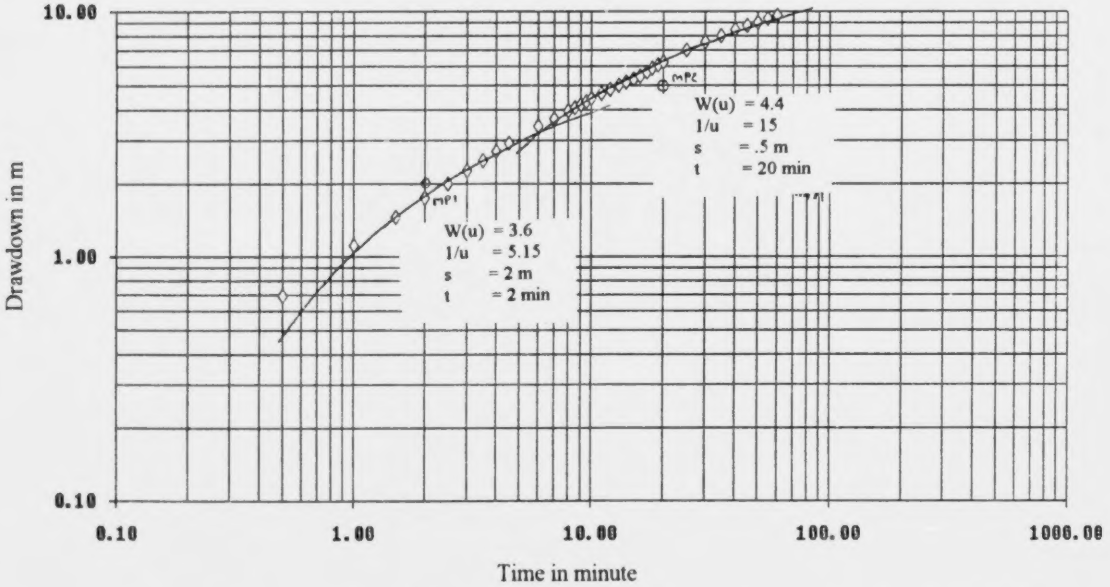
Theis fitting curve for fully penetrating and isotropic aquifer of well PWKC due to pumping well PWKC



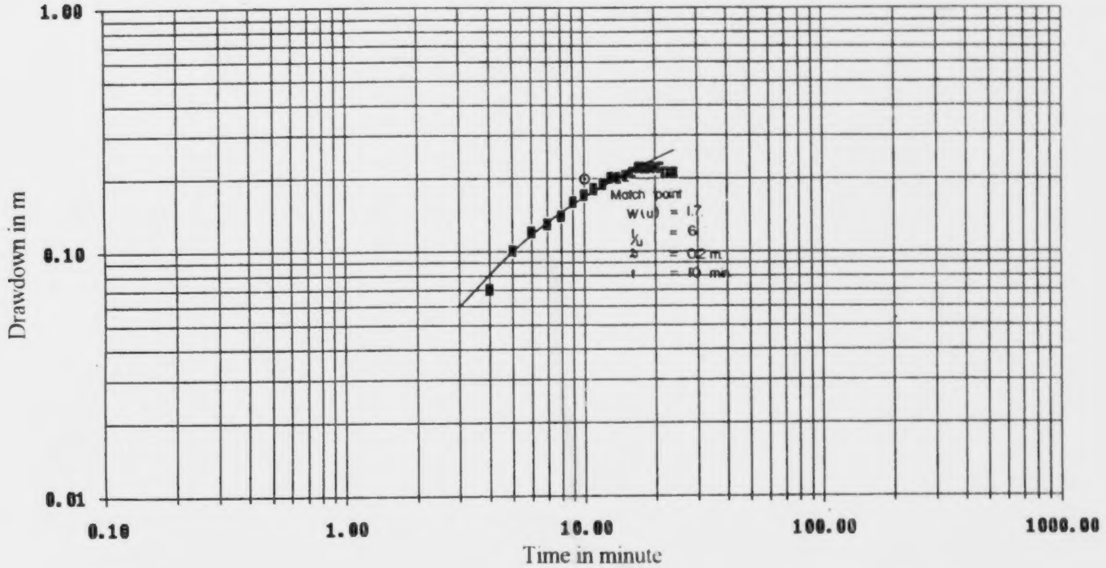
Theis fitting curve for partially penetrating and isotropic aquifer of well PWKC due to pumping well PWKC



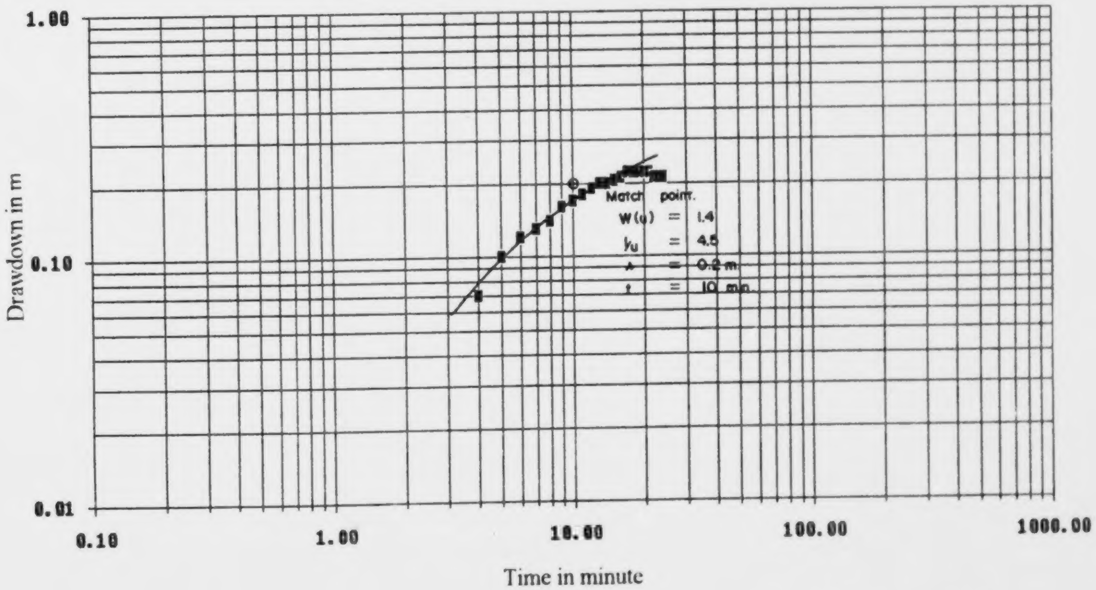
Theis fitting curve for fully penetrating and isotropic aquifer of well PWTW due to pumping well PWTW



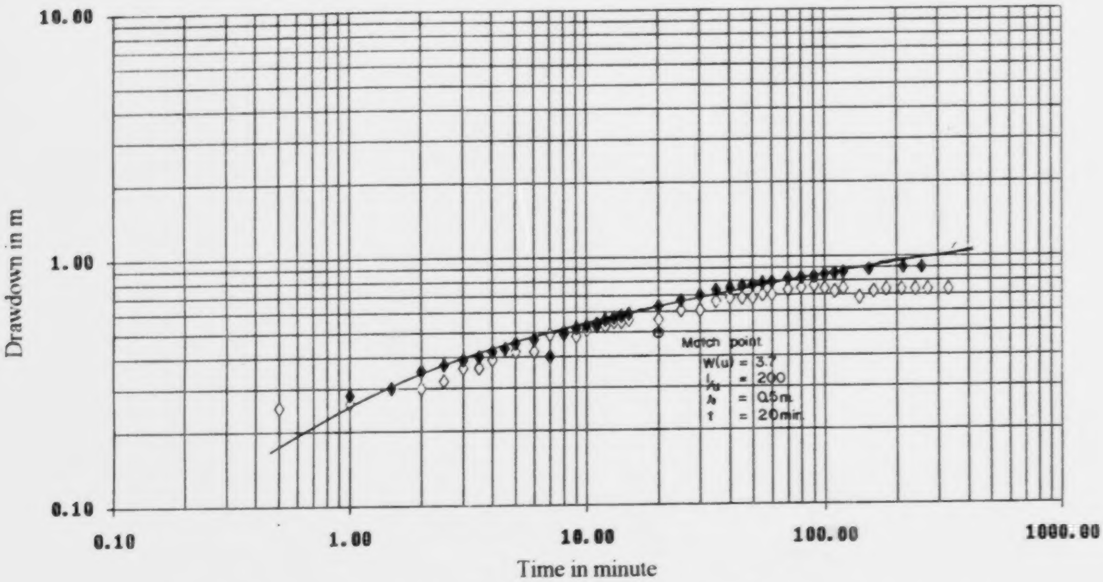
Theis fitting curve for partially penetrating and isotropic aquifer of well PWTW due to pumping well PWTW



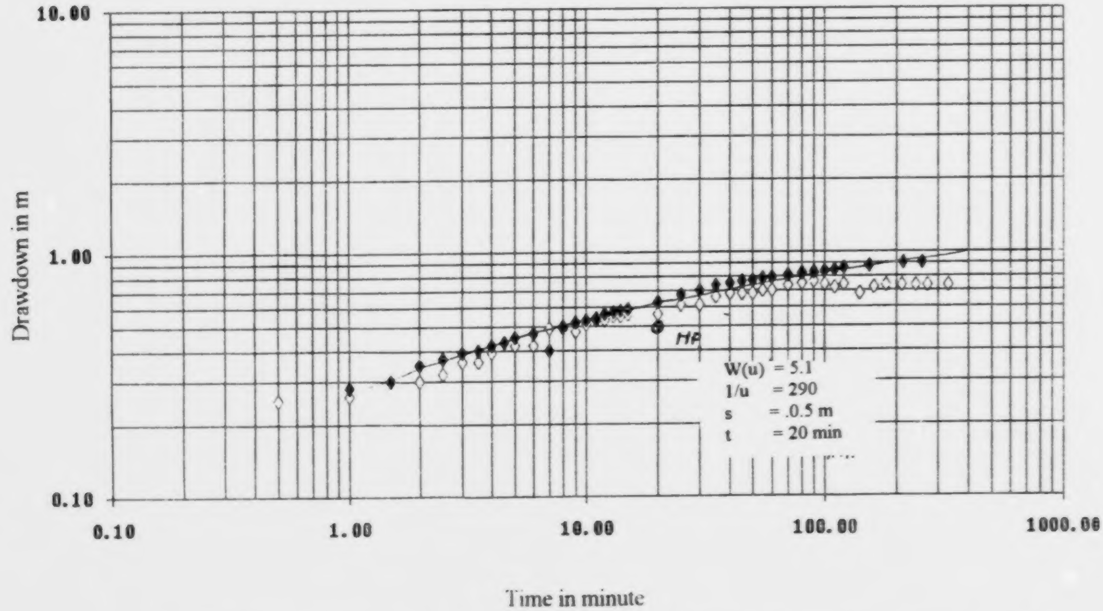
Theis fitting curve for fully penetrating and isotropic aquifer of well P11 due to pumping well PWKS



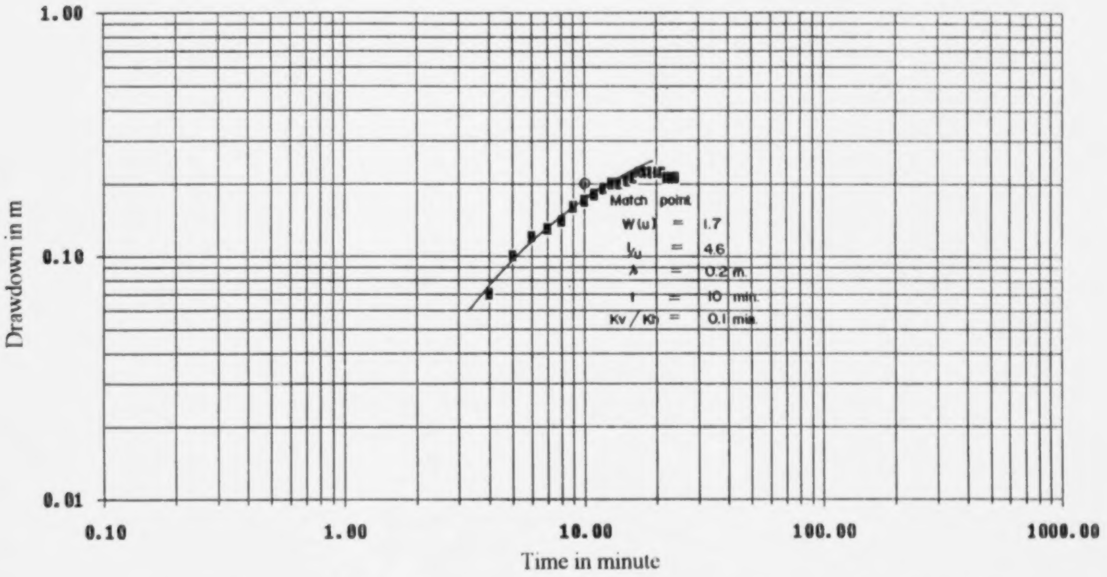
Theis fitting curve for partially penetrating and isotropic aquifer of well P11 due to pumping well PWKS



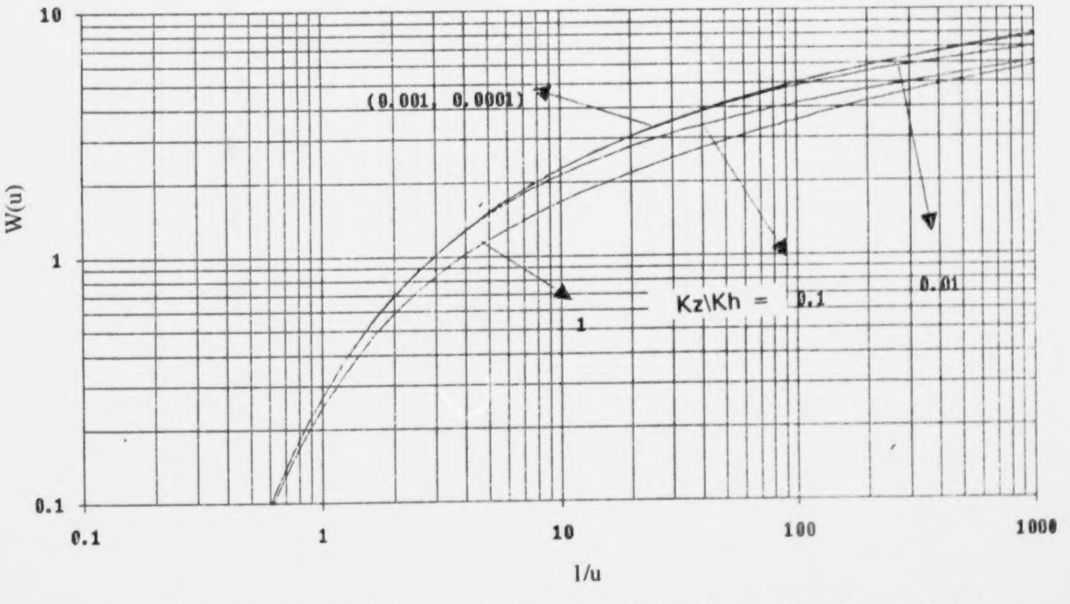
Theis fitting curve for fully penetrating and isotropic aquifer of well PWKS due to pumping well PWKS



Theis fitting curve for partially penetrating and isotropic aquifer of well PWKS due to pumping well PWKS



Theis fitting curve for fully penetrating and anisotropic aquifer of well PWKS due to pumping well PWKS



Master curve for partially penetrating and anisotropic aquifer of well PWKS due to pumping well PWKS

Appendix 7.1 Rainfall and rainfall tations in the Khon Kaen Drainage Basin

The data were collected from the meteorological Khon Kaen Station during 1952 -1985

(Khon Kaen Meteorological station, 1989)

MONTH	MC	CNB	BP	BB	HT	KS	TP	HY	MKK	KM	CY	UB	NP	KN	Av.
MAY	151.60	205.70	153.10	180.70	132.70	149.80	151.80	124.20	161.80	145.70	149.30	143.40	133.70	202.10	156.11
JUN	152.20	124.20	151.20	174.00	126.40	167.10	152.10	180.00	183.80	189.20	166.00	184.50	136.10	189.20	162.57
JUL	127.30	156.60	144.60	159.00	145.10	137.10	151.30	135.80	157.60	159.60	180.00	191.40	146.30	187.80	155.68
AUG	145.00	178.70	140.10	182.30	168.10	180.00	183.60	162.50	194.20	176.50	194.40	162.10	162.10	209.30	174.21
SEP	251.40	286.20	254.90	262.60	261.50	251.40	268.40	225.00	269.20	271.00	261.90	207.20	214.70	259.00	253.17
OCT	86.50	120.50	97.40	77.60	99.10	80.00	91.90	97.60	83.70	104.20	62.50	81.40	65.50	88.00	88.31
NOV	13.40	16.60	10.70	8.50	10.60	8.40	16.30	6.20	13.40	12.20	6.60	6.20	5.30	20.40	11.06
DEC	4.50	1.60	4.20	0.90	5.30	2.80	1.40	6.00	3.00	6.90	4.70	5.60	5.60	4.10	4.04
JAN	4.60	1.80	5.50	7.80	3.30	3.70	1.90	2.50	6.00	7.00	2.20	3.20	0.70	5.80	4.00
FEB	12.30	16.00	16.00	18.60	8.00	12.40	15.10	10.40	13.00	11.50	7.50	10.10	5.70	4.80	11.53
MAR	32.00	52.60	47.30	38.60	25.10	35.40	39.50	14.50	31.90	17.60	22.40	21.50	27.90	30.80	31.22
APR	69.60	56.30	69.90	69.30	55.50	65.30	75.20	49.50	60.80	71.80	63.40	79.90	42.10	54.40	63.07
ANNUAL	1050.40	1216.80	1094.90	1179.90	1040.70	1093.80	1148.50	1014.20	1178.40	1173.20	1120.90	1096.50	945.70	1255.70	1114.97

Rainfall stations in the Khon Kaen Drainage Basin

MC = MANCHA
CNB = CHONNABOT
BP = BAN PHAI
BB = BORABU
HT = HUAI TOEI
KS = KOSUM PHISAI
TP = THA PHRA

HY = HUAI YAI
MKK = MUANG,KHON KAEN
KM = KOK MUANG
CY = CHIANG YAN
UB = UBONRAT
NP = NAM PHONG
KN = KRANUAN

Appendix 7.2 Average monthly rainfall(RF)-evaporation(EV)-potential evapotranspiration(PE) in the Khon Kaen Drainage Basin by Thornwaite Metohd

The data were collected from the meteorological Khon Kaen Station during 1952 -1985
(Khon Kaen Meteorological station, 1989)

LOCATION : AMPHUR NUANG , KHON KAEN PROVINCE

MONTH	T	F	i	a	PE	RF	EV
JAN	22.80	0.97	9.947	3.836	72.022	6.00	154.20
FEB	25.60	0.91	11.853	3.836	105.372	13.00	161.40
MAR	28.70	1.03	14.093	3.836	184.912	31.90	211.70
APR	30.10	1.04	15.146	3.836	224.137	60.80	216.60
MAY	29.20	1.11	14.466	3.836	212.925	161.80	196.30
JUN	28.60	1.08	14.018	3.836	191.309	183.80	171.40
JUL	28.00	1.12	13.576	3.836	182.896	157.60	165.50
AUG	27.60	1.08	13.283	3.836	166.893	194.20	150.00
SEP	27.00	1.02	12.848	3.836	144.876	269.20	137.00
OCT	26.30	1.01	12.347	3.836	129.703	83.70	152.30
NOV	24.80	0.95	11.297	3.836	97.389	13.40	151.00
DEC	22.80	0.97	9.947	3.836	72.022	3.00	152.40
ANNUAL			152.821		1784.458	1178.4	2020.00

T = mean temperature(C) of the period in question degree celcius measure under the shelter
i = (T/5) ^ 1.514 (thermal index)
I = annual thermal index, sum of twelve monthly thermal indexes, i
F = correction coefficient, function of the latitude and the ,month , given by the table .
PE=potential evapotranspiration (PE =16*(10*T/321.5)^a*F): in mm.
RF= rainfal in millimiter
EV= evaporation